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DISCUSSION ON MR. HAZLETON'S ADDRESS CONCERNING THE REGISTRATION OF ENGINEERS.

(January 26th, 1927).

MR. HUTCHINSON : I suppose the registration of engineers is a thing which we have all dreamt of at some time or other. Most of us have looked upon it as a subject only for dreams, but I think we who are fortunate enough to be present this evening must realise that Mr. Hazleton's Society and its Committee have gone very far towards lifting it out of the realm of dreams, and putting it on a foundation of reality. I for one have spent a great deal of thought on this particular subject, and my mind has run along channels very similar to those which have been outlined this evening, but it has always struck me that the enormous field which our profession covers as compared with any other profession multiplies the difficulties to a tremendous extent. In fact, it emphasises one of the greatest difficulties of life, that is to get people

of various fields of thought to be able to focus on one particular point. When we talk of the registration of dentists, doctors or architects, we must realise that in those cases we are talking of the registration of a profession peopled with professional individuals. When you come to engineering you are considering a profession which is peopled mainly with employees. In the other professions the employees are naturally in a very small minority in comparison with the employers, the employers being individuals having no employees for their particular work. Occasionally they may have an assistant, but in the main they are individualists. There is only one very small branch of engineers with which you can compare the architect's profession and that is the consulting engineers. The same, of course, applies to dentists and the doctors, whereas we have to start off with two great headings; the employers and the employees. The employers are divided up into groups of different classes of engineering, the civil, mechanical, electrical, general manufacture, production, and so on, and employees are again divided up into similar groups, and those groups again are largely sub-divided. That puts another aspect in front of us, and that is, how are we going to convince an employer of engineers that the registration of engineers is not going to put the majority of his employees in a position which is perhaps stronger than he might desire. He will look at that point, naturally, before he will look at the fact that as an engineer himself he should do everything he can for the profession as a whole. One thing on which we have got to convince our employers is that engineers as a body are not putting this forward with any view of strengthening themselves as a negotiating body for conditions of employment. To convince the employing engineers of that fact, to my mind, is one of the very difficult aspects of the case. There is something very similar at quite the opposite extreme. In the engineering industry to-day there is a tremendous body of men practising what is called engineering but is not really engineering at all, or does not come within the scope of what engineering should be if this Bill is passed into law. I know many men who have been in engineering works a few years, yet the fact remains they are not engineers, although they fill a particular post by specialising, sometimes much better than many qualified engineers could do. A big opposition from that side has to be faced, and we have got to satisfy these people that there will be a means of their being able to go into the fold as engineers and that they will not become unemployed by the passing of the Act. That seems to me the second big fence we have got to climb. Then again we have got the very vexed question of a definition of the term "Engineer." Mr Hazleton has told us that when the Board of Trade asked for a definition it could not be provided. His Society has gone a great way in its Bill by giving up the attempt to define the term

"Engineer," but it has got something to do which is practically as difficult; that is to define what Institution is practising engineering. It is only a division of the same difficult subject. There are several thousands of engineering societies in this country who can claim to be in some degree technical. I do not know if there is an Institution of Bricklayers; if there is, they might come along and say, "We are engineers because the men who construct buildings are engineers, and we lay the bricks for them, therefore we are engineers." That has got to be defined, and it seems to me it is going to be nearly as difficult to do as to give a definition as to what is an engineer.

As regards to the best way to obtain the registration of engineers, we have heard to-night one way, and I think it is a very fine thing to find out that it has gone so far as it has, but it did strike me, to some extent, that the Society of Technical Engineers is putting the cart before the horse. It is introducing a Bill in which it suggests that a General Council should be formed. I think that by far the better thing would be to try and organise a meeting of influential engineers, including representatives of all the Institutions, and endeavour, first of all, to elect a central body to form a society to represent all the branches of engineering, and when that body is formed, then try to put forward a Bill. The first step would be that Institutions would have to affiliate themselves to that central body, then I think, provided they came in line sufficiently well, there would not be the slightest difficulty in getting the Bill passed. I thing that unless there is a body of that description in existence, whoever puts forward a Bill of this kind, will simply have the other Institutions up against it, because they will always feel "We might have done this and we are not going to fall in line and be led by the nose."

I could say a lot on this subject, but what I have said I think covers the main points we want to discuss to-night, and I feel certain Mr. Hazleton will take due note of our discussion and so gauge the opinions of the Institution of Production Engineers on this subject.

MR. W. E. I. GANNON, Member: I think I express the feeling of every member present tonight when I state that we are all very grateful to Mr. Hazleton for the lucid way in which he has placed this subject before us. Of prime importance is the question: "Should engineers as a profession be registered?" Not one but perhaps a thousand and one points have to be considered, but we cannot do other than recognise this point, that in the interests of the public, if not in the interests of engineering, it would be only a right and correct thing that engineers should be registered. The large employers, or the public, or those that have to negotiate with the engineering profession would have a standard of the knowledge of those with whom they are dealing. There are

some very important points that our President has put before us that are quite true. We have to realise that in the Medical profession the workman is actually the man that is practising, whilst in engineering we find this: that the chief controlling factor is seldom actually practising. A piece of mechanism needs the attention of the mechanic. A mechanic is sent away and his brain has to decide a great deal in that case. The man actually practices. Therefore there seems to be some difference between doctors and engineers. However, there is no reason why the workers, in a great many cases, should not aspire to reach the stage of registration, and consequently improve their their status. There probably would be some difficulty in defining who are engineers. Perhaps as Mr. Hazleton has said, in a little time to come members of societies will not be prejudiced, and the question will be dealt with by a standard of qualifications, tests, or recommendations by those who know the individual. I do not want to go into any detail upon this next point because I do not understand it fully, but it does perplex me that usually the people who are in controlling positions are seldom technically trained. I am certain that the concerns they are responsible for would be in a more flourishing financial position if they were. If in time to come the people responsible for the work were more highly trained individuals we could look for better results.

MR. H. MANTELL, Member: As everyone here is agreed on the general principle of registration we need not elaborate that point but should come down to a consideration of detail. It is unfortunate that members were not supplied with a copy of the proposed Bill which is to be submitted to Parliament. For some time I have had a copy in my possession so I am better placed than most people who are here this evening. Of the very many aspects of the question, I think that of professional jealousy is the biggest. Mr. Hazleton smiles as though he has already "had some," but it is a very real feeling on the part of the senior Institutions and one can quite understand it. That brings us to another difficulty, that of the seal. It is probably a minor point which has not been considered yet, but if a document bearing an engineer's seal comes into the possession of someone who is not an engineer it is good from their point of view, but can one imagine one of the very brilliant men of the Institution of Civil Engineers agreeing to use a seal which is used by one of the very dim lights of the Institution of Production Engineers. You have got to face the fact that the production engineer is not a widely known man at the moment, and I think perhaps to gain support (incidentally Mr. Hazleton has not told us what support this Bill is receiving from the Senior Institutions) it may be advisable to so design the seal that it would indicate the status which the holder enjoys within the profession. It would probably detract from

some of our own importance, but, facing facts, we had better make provision.

The Society of Technical Engineers says it does not intend this measure to create a monopoly. In the section which allows the use of the seal there are certain things laid down which cannot be performed, or which are not permissible in the eyes of the law unless they bear the seal of the engineer. I think that creates a monopoly. That is only a small point and I quite agree with the monopoly, but probably if it got into Parliament that would be one of those quibbling things on the question of detail which would upset the Bill. I understand there are certain persons in Parliament who are not favourably disposed towards monopolies. If monopolies are not mentioned they probably would not oppose it.

There is another thing which affects us very strongly. There is no guarantee in the Bill that the Institution of Production Engineers can come into the fold automatically. That is, I do not see it, it may be there. A preliminary General Council is provided for and the nominees of certain Institutions already formed are specified as members. As soon as the Bill becomes an Act those people will automatically be nominated to form a General Council. There are others who will serve on the General Council who will have to be elected after the Bill becomes an Act. I do not see anything in the Bill that will ensure that the Institution of Production Engineers, amongst many others, will have anything to say in selecting those people. The people who will automatically come on it are: the nominees of the Government appointed by the Privy Council, four from the Services, four from the Senior Institutions (i.e., the Civils, Mechanicals, Naval Architects and Electricals), and then six other persons from other Institutions and the Universities will have to be elected by the General Council, and they will say, "We have got to elect some other fellows to join us, who shall we have? We have got the North Eastern Engineers, the Manchester Society of Engineers, the Institution of Production Engineers, who are they?" There is no provision to prevent that sort of thing. I do not see it, if it is there I have overlooked it. It is something upon which we ought to be clear. We do not want to provide one of the supports for the guillotine that is going to decapitate us.

Coming down to other details, there is one section which gives the General Council several rights, including the cancellation of registration for heinous offences or unprofessional conduct. We have heard a lot about unprofessional conduct lately in connection with the Medical Profession, and I think before we sanction anything so loosely worded in the legal sense, we ought to define more clearly "unprofessional conduct." There is one good clause which is, I believe, one step in advance of the of the Medical

Acts. Anyone with a sense of grievance can appeal to the High Court, but there does not appear to be any clearly defined provision for a personal appearance before the General Council. I think that should be laid down if this is to become law.

There is another thing: the question of fees which Mr. Hazleton explained, are purely a suggestion at the moment. It is provided in the Bill that £4 goes to the Institution in which the engineer is interested and 25 per cent., or some percentage agreed upon, goes to the General Council. If a man wishes to join another Institution he may do so if they agree with his qualifications. He is allowed to join that Institution without any further fee, which means that the Institution of Production Engineers, looking at it from quite a selfish point of view, can be swamped by members who pay nothing at all to that Institution, yet drain on our accounts by increasing the cost of publishing the Proceedings, etc. That, of course, is always subject to Mr. Hazleton's correction.

The right to appeal against any decision of the General Council is reserved in the Bill. I think there should be some provision as to the standing of the engineer pending the hearing of the appeal. Does a man carry on as hitherto before his appeal has been made, or is he suspended from practising until the appeal is made? Some of the penal clauses are very severe, one of them, No. 7, "An unregistered person who later than two years after the commencement of this Act uses the title of Engineer with or without any other qualifying words or descriptions, such as Technical Engineer, Civil Engineer, or otherwise, shall be guilty of a misdemeanour, and shall on summary conviction be liable to a fine not exceeding £50 for each offence or a term of imprisonment not exceeding three months." But that throws the selection of the sentence on to a magistrate. I should suggest that after the words "not exceeding £50 for each offence or" the words "in default" should be inserted. It would be rather terrible to have anyone sent to prison for a civil offence. The Registrar of Births, Deaths, and Marriages, has to notify the death of a registered engineer. If an engineer goes abroad and dies there, there does not seem to be any provision for notifying his death to the General Council. I think that should be done through the Consular Service.

The seals I have already dealt with, but the penalty for wrong use of seals is £10, or imprisonment for not more than 14 days. In my opinion that is a worse offence than calling one's self an engineer without being qualified to do so, for it is a deliberate attempt to mislead. It is very closely akin to forgery and yet strangely enough the penalty is quite a lot less.

Certain engineers are exempted from the use of seals. The Bill says that foreign engineers shall not be subject to sections 18 and

19. I think they should be liable for the improper use of seals, otherwise a man can design a seal and use it, and there is nothing in the Bill to prevent him from doing so.

There is one other clause which will bring quite a lot of opposition. There are a tremendous number of firms in this country whose title includes the term "Engineer" or "Engineering." They might not be disposed to support the Bill at its present stage, or for the next few years, because of the expense they might be put to in changing the title of their firm.

Finally I note that the General Council shall also be empowered to pay to Members of the General Council such fees for assistance as it may consider proper to pay for legislating the profession. I do not think that is a very desirable feature. There does not seem any reason at all why a man who serves on the Institution of Mechanical Engineers or Production Engineers without any fee or reward should accept it when he serves on the General Council of Engineering, and to come back to the constitution of the General Council, I am also strongly of the opinion that it will ultimately weaken the status of the engineer if that body includes representatives of employers and employees. The tendency, I feel sure, will be to interrupt technical and professional debates to discuss purely industrial questions.

MR. HAZLETON: I have been very interested in the remarks that have been made by the various speakers. I may say that we welcome most heartily the sort of criticism which has been put forward. There has not been, from our point of view, nearly enough so far, because on the details of a measure of this kind there must be a great many points where searching criticism will reveal weaknesses and differences of opinion. It is very well to have them looked into. I do not agree with a good many of the views put forward by Mr. Mantell. For instance, some of the minor points, with regard to the question of fees. Having put a statutory obligation upon a man to fulfil certain duties, and they have to come from various parts of the United Kingdom to attend meetings their expenses should be paid. MR. MANTELL (interposing) said, "The clause allows 'fees **and** expenses.'" MR. HAZLETON (continuing): There is another point, the question of firms who at present call themselves Electrical Engineers, or Engineers of any kind. Certainly a good many firms who have not got qualified engineers will have to go to a great deal of expense, and I think it is right that it should be so; the men who are at present describing themselves as architects will have to do the same thing under the Architects Bill. You cannot have a measure of this kind without some inconvenience of that nature, but it is really a very small matter. The more serious thing is, of course, the attempt that we have made to reserve the title of engineer for those who are qualified for registration, because that will

affect men like mechanics who are customarily described, in loose language, as engineers. They may feel a certain sense of grievance of being deprived of that right, and we have had to consider that very carefully knowing that it would involve some opposition, particularly, for instance, from the Labour benches in the House of Commons. The Architects are doing it, and it has been done in Engineering Acts elsewhere. At least, it is a thing we may have to bargain on and by putting it at its highest at the outset we have something to give away. The most important question, of course, that Mr. Mantell dealt with, I think, was the constitution of the General Council, and there you must bear in mind the fact that the Society of Technical Engineers, which is a very small body and not a very widely representative body, was taking upon itself, in the first instance, a very big thing in making these suggestions in black and white to put before the profession as a whole. We knew perfectly well that there would be a very great amount of criticism of a sort, entirely independent of the particular merits of the proposals we had to make. It has been quite frank. Mr. Mantell has asked what support the Senior Institutions have given to a measure of this kind. It is inevitable that people like the Civil Engineers and similar bodies should say, "Who are these people proposing to dictate to the profession?" In the earlier stages it was unlikely that these proposals would be considered impartially on their merits, but the consideration was bound to be influenced by the quarter from which they were put forward. That has been the case, and the Senior Institutions have not been disposed to come to close quarters in connection with the discussion of the details of the Bill. They profess that they are in favour of the principle of registration, but you must bear in mind that our sole aim in this matter has been to bring forward the question of registration to a stage of practical politics One way to accomplish this was to propose to a body like the General Engineering Council that it should consider the suggestion on the constitution of the Council which we have put forward, but we were advised that if proposals were privately made to a body like the Engineering Joint Council the chances were they would be smothered for years and years and nothing more would be heard of it. Another way was to follow the example of Italy where a professional body similar to ourselves brought the issue of registration into a living question and secured its passage to the Italian law. We made that example our justification because on this question so many interests are concerned that unless agreement on a proposal, such as your Chairman suggested, is obtained, that is the formation of a thoroughly representative Committee or Society to which the various engineering bodies would affiliate or contribute their quota, it is almost impossible to provide that there are private consultations in the first place. We considered that

point very carefully and decided that much the best plan was to provide the best proposals that we could devise and to table them for the whole of the profession to see. That would enable them to criticise and judge the actual proposals and it would be possible to get the Institutions to consider them on their merits right from the start so that we can live down any prejudice against the originators. That is the stage we are at at the present time. We have made overtures to the Joint Engineering Council that the best plan would be, not to proceed with this Bill as it stands until the Joint Engineering Council has been able to organise the appointment of a thoroughly representative committee of the Institutions to consider the whole question. I want to say, that there are two sides to this from the legislation point of view. Suppose some of the senior Institutions will have nothing to do with it, and are obdurate in their attitude. They have got to convince Parliament, if a measure is put forward, that their attitude is reasonable, and Parliament will not take a mere negative attitude from the Institution of Civil Engineers or any other body. Parliament would consider a measure of this kind on its merits. If it gets a day for its discussion at second reading the Speaker will certainly put it to the vote at the end of the day's discussion and I have grounds for saying that it will be carried. In the first place all private members' Bills are referred automatically to the various Government Departments that are concerned, and even although we did not appear to make any progress with this Bill last session, we have heard from various Government Departments that the Bill will not be opposed by them, so we can say, as far as the Government is concerned, the Bill for Registration will have plain sailing in the House of Commons. Labour members have been blocking it for reasons connected with the question of title, but I would like to say that as far as the second reading is concerned there will be a majority of the present House of Commons in its favour. If it gets a second reading the Registration Bill will be referred to one of the standing Committees of the House, and there it is considered line by line and clause by clause. When it gets to that stage it will be the duty of any Institution which considers itself aggrieved or which is not in favour of the Bill to come forward and state the reasons and grounds of its objections, and it will have to convince that Committee of the House of Commons that they are good grounds, so it is one thing for an Institution to say they will not support a Bill of this kind, but it is another thing to demonstrate that its opposition is not unreasonable.

Now on the question of the Constitution, I would like to say this, that Mr. Mantell's criticisms with regard to the drafting of the Bill are justified. We felt that in the first draft of the Bill that it was not for us to state definitely the constitution of

the General Council, but rather to indicate in outline the sort of make up we believed it should have. There were two plans, one of confining it to a very small number which would mean the restriction of the profession, and the other was to bring in all the existing engineering Institutions and bodies. Some people think that the better plan would be to compromise between those two extremes, and we have a provision under one of the clauses, Section 10, which provides that if any bodies are left out which consider that their particular section of the profession ought to be catered for on the General Council, that some of the existing Institutions should have power to set up sections. That, of course, might be very considerably strengthened but it was done with a view to avoiding the further multiplicity of Institutions. For instance, there was the question of setting up a Wireless Institution, but instead of that being done the Institution of Electrical Engineers has set up a wireless section within its own body. Of course, the American practice has been to consolidate their Institutions and so avoid the multiplicity we have here.

I need not say that on the very difficult question of representation under Clause 2 it would be from consultation with those concerned what the final provisions of that clause will be.

With regard to some of the other points that Mr. Mantell raised, I have made a note of them, as I am not in a position tonight to deal with them all. While they may be of detail, I am very much obliged to him for them and they will certainly be looked into. Your Chairman gave you some of the major difficulties that may have to be faced in the further consideration of this matter. Those about the employers are very important and I can only say in a general way that the fact that so many engineers are employees working for big firms, does distinguish them, and makes the question much more difficult than in the case of ordinary professional men, like doctors. The thing has been tackled in other countries and is in successful operation, so in spite of difficulties it should be done here. On the question of seals, I would like to tell Mr. Mantell that those clauses are not final in any way. We attach enormous importance to the general plan of those clauses dealing with seals. They are very difficult but they are only an indication of what we have in our minds, as we consider it would be helpful to the individual to have provisions of that kind. Mr. Mantell is quite wrong about the danger of your Institution being flooded; he misread the clause. It means a man will only have to pay the Statutory fee to the Institution through which he registers. If he wants to belong to more than one he will have to go before the Council in the ordinary way, pay their ordinary fees, and they may have him or not, as they please. The provision makes for uniformity. One Institution will not be able to say, "If you join us we will

give you a lower fee in addition to the Statutory fee." They would have to pay the membership fee.

I think that that covers the chief points. On further consideration I agree with Mr. Mantell about the severity of the penal clauses. I do not think that imprisonment should stand at all, the fine is sufficient. The fine is £50 in the Architects, and I think we ought to make it the same for the Engineers.

Mr. Gerard Smith, Member of Council: I hold a double honour in that, I believe, I am the only member of the Institution of Production Engineers in the Society of Technical Engineers, and I am the only member of the Society of Technical Engineers in the Production Engineers. I only wish very sincerely that I had had Mr. Mantell in the past year or two to back me, because in the Councils and on the Committees of the Society of Technical Engineers I have undoubtedly been the awkward member. For this reason, I am perfectly certain if this Bill becomes law this Institution has to decide whether it shall be engineers or not. If it is going to retain the name of Engineers it will have to fall into line with the dictates of the Senior Institutions. We have, I believe, a divison of opnion to-day as to whether we should open our doors to producers in general or open it only to producers in the engineering profession. After all, I think our position as engineers is one of the American definition. An engineer is "a fellow who can make for one dollar what any guy can make for five." There are many of us, and perhaps the best of us, who have never passed a single examination, and perhaps never attended a technical college, who have grown up in the shops and can hold our own with anybody on any particular job which is to be produced, and I do not believe you can draw a line with production or anything else. A man who makes a motor car is an engineer. A man who makes a piano is an engineer, and from that we progress by stages to the famous sausage manufacturer who we talk about so very often. I do not think the constitution of the Civils, Mechanicals or Electricals is such that they will recognise anybody as engineers who cannot pass the examination that they themselves set. I furthermore believe that they are entirely handicapped if they had to define the qualifications of a production man. It is a thing hardly anybody can examine, but our only hope of holding our name if this Bill, as it stands, becomes law, is to affiliate ourselves to perhaps the Mechanicals or to some other Institution, and so do what we have been trying to avoid throughout our whole existence, that of swamping our identity as a separate entity.

Mr. Gartside, Member: I think it would be a great help if we had some idea as to what constitutes a registered engineer in New York or in Italy. How do they draw the line in those countries that have already got Acts in force?

Mr. Hazleton: The registration is quite simple in the existing provisions in the Italian, New Zealand and New York Acts. There are certain authorities set up, some of them widely representative, and some of them narrow. In New Zealand very narrow. The whole of the institutions of the New Zealand Act are covered by a board of five, who set the qualifications. They have the power to fix qualifications to hold examinations and everybody must come up to the prescribed qualifications. In Italy, and New York there are similar boards. In New York its seat is at one of the Universities and works through the University much more than in Italy or New Zealand. In New Zealand there are exceptions for men who were working as engineers at the time of the passing of the Act; in future, only those will be registered who have got the particular qualifications required, whether it is the passing of examinations, or serving an apprenticeship, and so on. That, of course, is not set out in the Act, but is set out by the various regulations laid down by the authorities, and we will do the same thing here. The Architects, for instance, are going to do it through their Council. They will determine the qualifications and set the examinations. They do admit that for the start of registration (which is really legislation for the future of the profession) men, who ordinarily, through lack of technical qualifications would fail to qualify should be registered but later on it will not be possible to get that type of man on the register. Men who to-day call themselves architects or builders but have very little training will be admitted to the register, but after the Act has been in operation for two years it will be much harder for new men coming along to get on the register as architects. It is along these lines we will deal with engineers without the prescribed qualifications. It does tend to make a closed profession so long as you do not legally create a monopoly, and there may be something in the point about the seals giving a monopoly. So long as you do not make it a monopoly it means that a man can do engineering work but he cannot be admitted to the profession or placed on the register as an engineer unless qualified. You do not, of course, prevent firms in this country from saying on this job or that job you must have an engineer on the register having the prescribed qualifications.

Mr. Gartside: According to that it strikes me it is really necessary for the engineer to pass the examinations; it then becomes a purely technical matter. There are many branches of the trade where education is not necessary. Technical education is not an important qualification for it is based on practice which is built up on practice. There is a certain amount of technical knowledge, but the technical knowledge which is required in certain egineering trades is not sufficient to enable a man to pass an

examination to get into the Mechanical, Civil, or Electrical Engineers.

Mr. Hazleton: Is it important that that type of man should be known as an engineer?

Mr. Gartside: Absolutely. One trade which I refer to is the machine tool trade. The machine tool trade, apart from ordinary mathematics and a certain amount of trigonometry and geometry, does not require any great technical skill in the higher order of things. It is built up on practice, and it is a real practical engineering job. There are branches of science the trade is dependent on, such as chemistry, metallurgy and such-like branches, but they do not actually enter into the production of the article itself.

Mr. Hazleton: That is very interesting because the Chairman of our Executive Council is Mr. H. G. Williams, Secretary of the Machine Tool Trades Association; he is a Member of Parliament and he is presenting this Bill to the House of Commons.

Mr. Gartside: He is a very good technical man but is not a practicing engineer. In the majority of cases in the machine tool trade you will find the technical man is just out of the University and about 23 years of age. He is not very much use because his knowledge of the higher mathematics is not required. It is more of a practical trade, and that is where I think the difficulty will be in defining what is an engineer.

Mr. Hutchinson: We have an analogy there between dentists and his mechanics.

Mr. Gartside: Exactly, that is a very similar case.

Mr. Mantell: Regarding the importance of a machine tool maker being an engineer, which question Mr. Hazleton addressed to Mr. Gartside, one of the provisions in the Act is that no debt is recoverable by Law for an engineer's service unless it is performed by a registered engineer. The machine tool trade is already sufficiently precarious without being faced with a lot of irrecoverable debts.

Mr. Gartside: I am not concerned about the Act, I am more concerned with who is going to be registered. I will leave the Act to the M.P.'s and the legal people.

Mr. Mantell: It is important that the class Mr. Gartside mentioned should be entitled to the term Engineer providing they have qualifications in certain directions, otherwise debts that are incurred by them will be repudiated, and the repudiation will have the sanction of the Law.

A Visitor: I think the question of technical qualifications being necessary applies to the whole of the members of the Institution of Production Engineers. For production whether it is

machine tools, motor cars, or any other technical product calls for such qualification.

MR. GARTSIDE: I think we can safely say that all of us have got certain technical qualifications as well as practical qualifications. It is merely a question of degree; some trades require a much higher degree of technical qualification than practical and that is where the difficulty arises. In the bigger Institutions, the Mechanicals, for instance, I think an ordinary Matriculation will carry you a long way with them, but the higher up you get the better your qualifications must be, and the Civil Engineers I think are the worst of the lot. In the Mechanical Engineers, after a certain age people are admitted as members who do not need to have technical qualifications, but it is what they have done in their life up to that time, if they have carried a big scheme through, or been personally responsible for some very important piece of work, or have invented something of very great value to the community at large, then those men are admitted into the Institution on that qualification alone. They have no need to pass an examination. If the same thing applies to registration, get ahead with it.

The difficulty is that the Institution of Production Engineers (which is a smaller Institution, but may be quite as important in a small way), is in a different line of business. I look on the Production Engineers as essentially a practical Instution, and that is why I much prefer to come here than go to the Mechanical Engineers. If I want to know how many gallons of water flow through a nozzle in a certain length of time, I go to the Mechanical Engineers, because that is the class of papers you get, but here we get other things. Both are probably of equal importance, but the Mechanicals deal with the trade generally; and the Production Engineers get down more to individual requirements, and the difficulty will be in drawing the line, where you are going to give the man the registration, and where not? You will see in works where there is an organisation tree, it starts at the top with the works manager, and it spreads out right down to the ordinary workmen. Where are you going to draw the line? There may be one man below who may be far superior to the man above him on being put to the test, but the fact of the man holding that position may entitle him to registration, whereas the other man, a much better man, is not qualified. Now what are you going to do in a case like that. It looks, to my mind, like a difficuly it is almost impossible to get over, whether we are going to be satisfied with executive positions or technical qualifications.

MR. OAKLEY: Our last speaker has rather made me feel that the Production Engineers are essentially practical. That is true, because, as production engineers, we have got to look ahead to the future, to the young men coming along. We have started

with practical men, but I believe as production engineers and their work develops, it will become more scientific and more technical and the time will come when the production engineer will be a more technical man. The production engineer, our Institution has often told us, has a big field, and is becoming more scientific as years go on. Therefore, I feel we have no fear about this question of registration, in so far as it is going to be well covered by a council which will lay down all the definitions of the various qualifications which are necessary for a member to become registered, and I feel we shall be able to leave it to them as time goes on to tighten up, as it were, the necessary qualifications, so as to raise the status of the engineering profession as a whole, and then I feel the Mechanicals and the higher institutions as they are at present constituted, will have no need to worry about the Production Engineers. I feel it is up to us all to make the thing better, to become more efficient. The practical is very good, but the technical to-day is almost as essential as the practical. Young engineers in the shops are beginning to realise this. Even boys on the tools daily become more technical in their operations, and I hope you will look at it in the way I suggest.

MR. HUTCHINSON: There are just two points in the Act that I would like to mention, and on which I agree with Mr. Mantell. I think the question of fees and expenses may be indicative of other detail points in the Act. I think the word "fees" should be more clearly defined, and I hope there are no other points which are equally ambiguous. Also I disagree emphatically in the mention of employer and employees on the Executive Council. I think that would be a great pity for it is much better to leave anything in the nature of employers and employees out.

Mr. Gerard Smith mentioned that there was a division of opinion in our ranks to-day as to whether we should not admit all producers. From the point of view of those who at present govern the Institution, that matter has been entirely squashed. There is no question that the Institution of Production Engineers should include all producers.

With regard to the question of the duty of myself and the Council of circularising this suggested Bill. Between the last Session and the beginning of this we heard for the first time of this move, and we were asked to say whether we supported it or not. We decided, after giving it some cosideration, that it was much too big a matter to attempt to speak for the Institution, we further decided it would be much too big a matter to be dealt with by correspondence with the Members, and it was suggested that we should invite Mr. Hazleton to come here and address the Members. The report of this meeting will

go into our Journal, and not until that has been done and the Members themselves have had their chance of expressing their approval or disapproval, will this Institution express any opinion on its attitude toward this Bill?

I must say this, that I am agreeably surprised. I had no idea that the Society of Technical Engineers had made anything like the strides that it has made in the last few months. I want to make it perfectly clear that as an Instution we have not expressed any opinion for or against the Society of Technical Engineers in their project. After they have gone through the report, Members will be given an opportunity of expressing their opinion; the opinion of the majority of the Members of the Institution as an Institution. So far as the technical side of it is concerned we are technical men, and the Council do consider the technical qualifications of every new proposal for membership or associated membership very, very carefully before they accept anyone for membership in any grade.

Mr. Gartside lost sight of the main point. He is not going to suggest for one moment that a young fellow coming to-day on to similar work to his own could for one moment have a tithe of the technical knowledge that he himself has picked up through years of practical experience. No one suggests one cannot learn the technical side of the job by years of experience without actually having gone to a technical college. When we are at a technical college our main object is to learn how to learn. We leave college stored up with knowledge which we use afterwards, and very often the application is more important that the knowledge itself. Any body of engineers should realise that. The Institutions themselves would decide once they were affiliated and accepted under the Act, whether a man is a fit and proper person to come under their membership.

I must say I very greatly appreciate the way in which Mr. Hazleton has dealt with this subject to-night.

Mr. Mantell: I am very glad to express what is, I am sure, the unanimous opinion of this meeting, that is the pleasure we have had in listening to Mr. Hazleton, and also our appreciation of the courtesy with which he has handled any points which have been raised. In principle, at least, I am quite sure we wish him every success in the project in which he is engaged at the moment.

Mr. Gartside: In seconding that, I would like to make clear that I did not want to infer that members of the Institution of Production Engineers have no technical knowledge. I merely mentioned that in our branch of the trade a very high technical knowledge is not necessary. I did make a remark that we all have a certain amount of technical knowledge, which we have, even in the machine tool trade we are not without it.

(Members are referred to Note on page 168)

EDITORIAL.

(November, 1928.)

THE Engineering World is apt to look upon the activities of the Institution of Production Engineers as being appplicable onlv to the automobile and kindred industries. That is not so; the differences between the manufacture of motor-cars and the manufacture of, say, electrical equipment are mainly of degree and not of principle.

Recently we have read of large contracts going abroad because British prices were too high. Apparently with the idea of coercing those responsible for placing these contracts a public enquiry has been suggested. It has been stated that the low prices quoted by our successful competitors were due to the lower wages paid in the country where the orders were placed. By now we ought to have learnt that low wages do not necessarily mean economical production.

By all means let us have the public enquiry and let the terms of reference include an investigation of the works of those who seek publicity. Will it be found that they are organised on up-to-date lines, with machinery, methods and equipment abreast of modern knowledge of these important factors? Is floor space used to the best advantage? Are there wasted efforts in management or office organisation? Is every man given the best facilities to enable him to give of his utmost?

There would appear to be more practical common sense in an investigation on these lines rather than to complain that we cannot compete with foreign prices. In fact, a Past President of our Institution made a similar suggestion when he stated that the only justifiable interference in Industry by the Government was in the appointment of Inspectors to see that we are operating efficiently.

Without waiting for Governmental action the members of this Institution should find a strong incentive, in the deplorable state in which our medium and heavy industries find themselves, to bestir themselves to extend the scope of our work to those branches of our profession. Good management backed by effective equipment will do much to lessen costs of production and there are none better qualified to speak on this subject than Production Engineers

Finally, to reduce labour costs does not mean a reduction in wages, higher wages can be, and should be, the outcome of an intelligent application of the technique of the science governing "lower costs per piece produced."

CYLINDER BLOCK PRODUCTION.

In Lots of 25, 250 and 2500.

Being a paper presented to the Institution on Februry 25th. 1927, at the Council Room of the S.M.M.T., 83, Pall Mall. London, S.W.1.

By H. Mantell. Member

BEFORE discussing those details which directly concern the Production Engineer it will be as well to mention some which, indirectly, greatly affect our problems. These, being outside our jurisdiction, can only be influenced by the exercise of suggestion, bringing home to those responsible a realisation of the fact that the whole being always greater than the part, it behoves each part to co-operate with its fellows to benefit the whole.

Much has been said at our meetings and infinitely more has been written about designers. At their door are laid many sins, yet the author strongly advocates a deeper recognition of the position as it really is. Assuming for the purpose of the case that designers have a general knowledge of production methods we find cylinder block (or any automobile component) design conforming to one of two conditions. On the one hand there is the block designed for a car appealing to a relatively exclusive clientele; on the other, the car which is being built down to a price. Under the first condition the designer will pay full regard to those technical details, also details of lay-out, which make for high efficiency and accessibility respectively. Under the other condition the main consideration will be ease of production. If a designer can combine the two, then he is indeed a jewel amongst men.

It only seems necessary to impress upon designers two points and these apply to both classes of cylinder block. One: remember to provide adequate locating and clamping surfaces. The other: remember that, as it is an elementary factor in automobile efficiency that the walls of the cylinder barrel should be of uniform thickness, provision should be made to enable the machine shop to maintain concentricity between the bore and the outside diameter of the barrel.

Foundry work is also mentioned as indirectly affecting our problem because in most cases it is outside our control. The author has watched, with interest, the growing support given to the British Cast Iron Research Association and hopes that all Production Engineers will persuade their managements to give the Association their active support. Upon the results of their research rests to a large extent the answer to the question of uniformity of machineability. When discussing production times one frequently

is met with "Oh! but that is in America!" This expression is considered a tacit admission that in one, if not all, phases of production American practice is better than ours. To say that the better machineability of material is accounted for by the use of lower grades of material is a mis-statement. Comparing cars in the same class the chassis materials will be found to closely conform to the same chemical and physical tests—excepting, to us, the vital one of machineability. A pressing need exists for the accurate determination of this property and it is hoped that this will be a question which this Institution will first tackle in its efforts to make official recommendations to the engineering profession. Brinnell hardness figures are of very limited use; for instance, upon one occasion it was desired to check the Brinnell of the cylinder block of a high grade English car to compare it with average American conditions: the English block gave a reading approximately 10 per cent. below the American yet indisputably the American blocks are more amenable to machining.

In the preparation of this paper any opportunity has been taken of discussing relevant topics with engineers in all branches of the industry. It is surprising how many are content to take the casting as it comes from the foundry and put it into the machine shop without prior annealing or pickling. One engineer was definitely antagonistic to the latter process on the grounds that however much rinsing followed it could not chase the pickling acid into the innermost depths of the pores and so left it there to the ultimate detriment of the casting. An academic point not justified by practice. Against annealing is raised the objection of the initial cost of the requisite plant and its maintenance in operation. Granting this, in the case of small requirements, there does not appear to be any reason why the foundry could not undertake this work; the increase in the cost of the casting would be offset by the greater freedom from blunted and broken tools with the consequent greater production.

There are two schools of thought in the heat treating field; one advocates the process before any machining is attempted, whilst the other suggests rough machining and then heat treating. The author favours the first for then a clean run through the machine shop is possible. If the casting is properly annealed then the stresses set up in the roughing operations tend to release themselves if the block is allowed sufficient time between major operations; this being accomplished by a suitable arrangement in the sequence of operations.

To give the machine shop every chance to maintain continuity of production it is suggested that castings be subjected to the following treatment before being handed over to the machinists.

Heat to approximately 1430 deg. F., soak for an hour then cool very slowly. Pass through a heated pickling bath of a 10 per cent.

hydroflouric and sulphuric solution (the sulphuric attacks any oxidised metallic skin and allows the hydroflouric to clear the silicon) then thoroughly rinse.

This process brings us to the machine shop and it will be as well to explain at this juncture that the title was given to this paper at its conception—another illustration of the folly of naming a thing before it is born. Ignoring the quantities mentioned the paper can be better described as an attempt to examine the differences and to find the common ground under varying conditions of production. Firstly, the small quantities with which many British manufacturers are concerned, secondly, the larger quantities which some of them are now tackling with success, and lastly, the methods of some of the large producers in the U.S.A.

An examination of many lay-outs has drawn attention to the diversity in types of machine tools used in order to achieve the same end; this diversity in some cases giving rise to bitter and biased controversy. It is hoped that the mention of these varying methods will bring out in the discussion the opinions of those present this evening.

Milling machines offer the first contrast and provide the first opposition. With small outputs it is usual to find a Vertical Miller employed; the next step being the ordinary Plano-Miller and ultimately the Differential and Drum Types of Millers. With an installation of five of these latter machines (four Differential and one Drum) a production of a block finish milled on the top, bottom, sides and two ends in a cycle of 2 mins. 20 seconds has been attained, the total machining time being 11 minutes 20 seconds.

Opposed to the use of milling machines for this operation are those who favour the use of Surface Grinders. It is said that milling machines call for a large machining allowance to enable the cutters to get under the hard skin, whilst an abrasive cutting agent will take the hard skin in its stride. Against this can be set the improvements in foundry practice which, almost daily, produces castings more amenable to machining right out to the surface. From an examination of facts which have presented themselves it appears that if grinding gains the ascendency then Britain can claim its introduction for it is only quite recently that the use of this method in U.S.A. has come to notice. Over here, it has been adopted by several firms, one grinds four faces, removing from 3/16 in. — 1/4 in. from each face in a period of 15 mins.; the surfaces are required to exclude "daylight" and opposite faces must be within 0.002 in. of parallel. Another firm, using another make of machine, can only achieve the completion of three surfaces in 30 mins. In the latter case the same depth of cut is taken and the approximate areas of the respective surfaces are the same: it therefore becomes necessary to examine the difference in results. The first manufacturer uses a machine with a rotating

table against his competitor's planer type of table—idle time for loading accounts for some of the difference. It is thought, however, that the larger share of the difference can be apportioned to the lack of enthusiasm in the second plant. Grinding, to them, was no good—consequently it wasn't, isn't, and will not be, if the shops can help it. Their milling time is very little better than their grinding time, it is certainly worse than their competitor's grinding time, yet, with plant at their disposal they will not get down to the job in an attempt to equal results being obtained on similar work. This attitude, unfortunately, is fairly rife; the author has been told many times that although a certain machine tool or appliance offered many advantages, if the shops chose to damn it they had it in their power to do so. The effect is the same as that caused by the workers' dislike to a labour-saving device but the causes are different; in the latter an economic cause is to be sought, in the other conservatism underlies the opposition. Returning to the Milling versus Grinding question; the best milling practice is still ahead of the best grinding but the figures quoted are only obtainable by the use of plant which is economical on large outputs. An average of milling results on production similar to that required by the exponent of the best grinding method gives a cycle of 12 minutes; this is still in front but it seems that the grinding machine is still called upon to remove the machining allowance provided for milling and has not yet been given the advantage of "closer-to-size" castings.

It sounds impertinent, but is known to be necessary, to suggest to Production Engineers that, when examining the relative merits of contrasting methods or even of different machines of the same type, it is essential to prepare an estimate which takes into consideration **all** the factors. Here is a list, (the author will be pleased to receive suggestions on any factor that has been missed):

Investment and Depreciation value of machine and tool equipment.
Floor space required.
Power consumed.
Estimated or known cost of maintenance.
Tool upkeep
Idle time due to changing and / or resetting tools.
Floor to floor production ***per day*** *(not per piece).*
Operator cost.
Actual value per piece immediately it has left the machine (this not only gives the cost of production on the machine but takes into account any costs incurred or saving affected in preparing the work for that particular operation.)
Actual value of any saving effected or cost incurred in subsequent operations.

It is thought that these factors cover one-job machines; obviously when considering machines used on varying components, change-over facilities have to be considered.

Boring machines for handling the cylinder barrels next claim

attention. One lay-out has recently come to notice where the whole block is being machined on a Vertical Miller and a Radial Drill; the latter machine looking after the boring operation amongst others. The contemplated output is 2 per week with provision for expansion as demand grows. The plant seems elementary, but an examination of the jigs and fixtures reveals very careful thought in those directions and if the other sides of that particular business get down to their job in emulation of their confreres on the production side, then the 2 per week will be left behind very quickly. Quite a number of small plants bore their barrels on an improvised machine made from an old lathe bed and headstock. Some are satisfied with using a single boring bar, others achieve multi-boring with the use of a geared head. It is doubtful if the latter arrangement is much or any cheaper even in first cost, if all expenses are taken into consideration, than the orthodox Multi-Spindle Vertical Boring Machine. For convenience these latter may be broadly classified as (1) American, in which the work is located under the spindles, and (2) Continental, in which the work is above the spindles. An objection to the latter type is that the cutting thrusts are generally only absorbed by the holding down clamps whilst the American type of machine permits this duty being undertaken by the whole of the table casting. Further, in the Continental type there is always the risk of C. I. dust getting into the spindle bearings however good the arrangements made for its exclusion.

As most British and American manufacturers favour the "American" type of Boring Machine the others will be ignored excepting any examples which occur in special machines.

In Cylinder Boring there appears to be very little difference in machines used in small, medium and some large production lay-outs. Other large output lay-outs make use of the standard elements of the ordinary machine used in conjunction with indexing tables, in effect two or three machines on one base; providing well designed labour saving fixtures are installed in conjunction with a good conveyor system one man can look after a two station fixture. All Cylinder Boring Machines should be equipped with an exhausting system to get the cuttings away at once; this saves labour in collecting the cuttings and reduces the time required to clean the fixtures when changing castings. Incidentally, those machines which do not lend themselves to the application of this system should be equipped with compressed air; few things are more depressing to witness in a machine shop than an operator's attempt to clean a fixture with a domestic hand-brush which, if not bald, is usually very "thin on top." One also looks for a greater use of compressed air or hydraulic power as the gripping medium in fixture design. There will then be fewer inquests as to why "Bill's" castings are always more liable to be distorted than "Jim's"; the inquest usually revealing that "Bill," being

puny, calls to his aid a length of piping when tightening up.

At one time American practice tended to perform other operations whilst boring was in progress; one instance being milling one or two surfaces whilst the bores were being machined. Whilst on paper this showed a saving, two disadvantages have swung practice over to the use of " one-job-at-a-time " machines. It the first place the machines were " man-killers " in that when they were going it was a Herculean effort to keep them fed for the designer of the machines went whole-heartedly into the job and laid out for three or more blocks at one pass of the head. The other disadvantage was that cutters seldom "broke down" together, hence one side of the machine would be unnecessarily idle whilst the other received attention.

Although, as previously mentioned, Cylinder Boring Machines are now almost always true to a type there remains a big scope for a reduction in the diversity of cutting tools used. Of the many single, double and multi-tools used and the almost as numerous methods of using them, the author is of opinion that the following is likely to provide the best results. In all cases use top and bottom guides running in bushes integral with the fixture; the drive being through a floating coupling.

Hog with a four-bladed hogging cutter approximately to within 0.080 in. of size; run at about 55 ft./min. and use a feed of 1/16 in/rev. When next the sequence of operations brings the block to a Boring Machine, use a bar carrying a single-point tool for straightening and semi-finishing and finish with a two-bladed floating reamer mounted immediately behind. The first tool should increase the diameter of the bore to within 0.020 in. of reamed size and the floating reamer (which can be made to hold size readily to within plus or minus 0.001 in.) will finish to the diameter which leaves the predetermined amount for the final sizing and surfacing process. With any finishing process other than grinding it is advisable to get as near size as possible so that the "cleaning up" tool will only have to remove ream marks. In some plants this gives rise to a demand for a uniform size of bore in any one block from the reaming process. Selective assembly will look after any possible variation between blocks but for smooth engine performance it is felt necessary to have all the bores the same in any one block. To meet this many manufacturers now perform reaming on a single spindle machine (this also applies to American manufacturers) which upsets the foregoing semi-finish and reaming layout until large outputs are required. Then a multi-spindle machine is used which instead of operating on one block, operates on as many blocks as there are spindles; the blocks being placed at right angles to the common centre line of the spindles. Thus each bore in each block is reamed with the same reamer yet a number of bores equivalent to a complete block are finished at each pass

of the spindles. Reaming should be performed at about 25 ft./min. with a minimum feed of 1/8 in. /rev., one American firm producing a car of fair renown using a feed of 3/8 in. /rev.; the tendency in this country being to dwaddle over this operation.

Whilst the finishing of the bore is usually the final machining operation the process will be dealt with at this stage. A multiplicity of methods are available and most are in use. Dealing with those in least favour or which are now practically dead we have Broaching, Rolling, the Push Ball method and Lapping. Broaching appeals as the ideal method for size, finish and low tool upkeep. Unfortunately (from the Production Engineers' viewpoint) automobile performance calls for water jackets and other cavities which in turn necessitate webs; these give the cylinder barrels different wall thicknesses at various places, consequently at the thinner sections one invariably gets a " spring back " with detrimental results on the parallelism of the bore. The author has met one Tool Designer who claimed to have tackled Cylinder Broaching successfully (after co-operation with the designer of the car) but as his firm have now ceased to manufacture broaches and the car in question is not now being made, it has not been possible to watch actual performance or to obtain up-to-date data. Rolling suffers the same disability as Broaching, as also does the Push Ball method. This latter process may not be known to several: it arose from an attempt by a ball bearing manufacturer (not British) to get cylinder bores finished by pressing a hardened steel ball through the barrel. Closing of the pores was claimed (with reason) as the technical advantage whilst from a production point of view speed of operation and almost indefinite life of the tool were advanced in support. Not only did unequal wall thickness militate against this process but the ball always followed any lack of symetricalness about the centre line of the bore. Lapping is good but too slow. The more popular methods are Grinding, Honing and Reaming. The last process is included because of the number of cars finished that way and not because of the number of manufacturers using it. Grinding, at present, is most popular in this country but is being superseded by Honing, which is alreay practically in universal use in the U.S.A. Commercially and technically it is better than grinding, therefore the older method will not be discussed further. Honing, even in its infancy, proved the claims just made—always providing the user got down to it. Now we are getting together various results, and whilst at first a lot of them appear to be contradictory upon examination of all factors, reliable data is being obtained. It is not proposed to describe any particular make of hone, it being sufficient to say that one which includes a definite stop in its mechanism is necessary for a successful exploitation of this process. The operation was developed with the aid of a Drilling Machine to give the

required reciprocation and rotation and it naturally followed that the early Honing Machines were drilling machines fitted with mechanical means of obtaining reciprocation. In evolving honing it was, perhaps, naturally, considered better to reproduce as far as possible the actual working conditions in the cylinder; therefore the reciprocations were in the ratio of about 6 : 1 to the rotations. In practice this tended to the early destruction of some of the Honing machines so that the ratio was reversed and that is the present practice. Cutting speed should be between 160 and 200 surface ft/.min.; on a 2½in. hone we get a speed of 245 to 306 r.p.m. with a reciprocation of 40 to 50 strokes/min. Of recent months a new machine has been introduced in which the reciprocations are obtained hydraulically; this suggests a bigger rate of reciprocation without the risk of disintegrating the machine, and, in any case, definitely allows for a variation in the length of stroke and also in the ratio between r.p.m. and strokes/min., both of which are only variable on a mechanically operated machine within certain limits and even then not readily. The hydraulic machine is also being successfully used for multi-honing; the process generally being to run the machine until size is attained in one or more (but generally all) bores; any bore undersize being rectified on a single spindle machine. For C.I. cylinders carbide of silicon is, of course, the type of abrasive used, 80 or 120 being usual grits in U.S.A., but it appears that over here it is necessary to use one much finer until we become accustomed to the "honed" finish. It has been found by experiment that a highly polished surface lengthens the time required for the piston rings to "bed in," the lines of almost infinitesimal depth left by a 120 grit stone facilitate "bedding in" the rings, yet are entirely obliterated on the test block or within half-a-dozen hours on the road.

From the nature of the operation the production time does not vary in direct proportion to the amount of metal to be removed; the first 0.0015 in. comes out in about 1 minute, after that, when all the reamer marks and high spots have been removed, the time increases considerably so that the next 0.001 in. will probably take 1½ minutes. The necessity for a "tight" reaming operation is apparent. Americans having got down to the grit and grade of stone suitable for their C.I. are obtaining 300 or more bores per set of stones; here we are still striving for data on stones and the best performance within the author's knowledge is 100 bores. Kerosene is used as a coolant; failing that paraffin mixed with screw machine oil in the proportion of 4 : 1. The coolant should flow generously and drain into a settling tank before being filtered back into the reservoir.

A few typical American results will be quoted before leaving this section of the paper.

Using a mechanically reciprocated machine, 62 six-cylinder

blocks are honed one bore at a time, using hand indexing in conjunction with an improvised fixture, in 7 hours 40 mins., which equals approximately 1-1/4 minutes per bore. Size of bore 2.6875; 3.7 H.P. used. From .002 to .003 removed from a reamed hole and final size is to within .0005 in. which looks after inaccuracies of size, roundness and parallelism.

A 6.500 in. bore with from .003 in. to .005 in. to remove due to impossibility to control reaming operation any closer took from 1 to 2 minutes each including handling time. A 5 H.P. moter used.

On one car of high standing a final reaming cut is taken **after** the cylinder studs are set; (this, incidentally, happens at one of the plants where one-reamer-one-block-multi-reaming is done). The block then goes to a hydraulically operated multi-honing machine. Fine stones are used and the machine is run for a predetermined time; about 1 minute. Any bore not then to size is dealt with on a single spindle machine. The author is assured that this latter machine is more of an insurance than an active producer. At this plant reciprocations are faster than revolutions, being in the order of 115 (230 strokes) to 67. Actual production figures are:—800 bores per day of 10 hours and of these the average of rejections over a period immediately before the author's correspondent communicated this information was only 1 per cent., that is 8 bores a day had to be brought up to size on the single spindle machine.

Machines for Drilling and Tapping will next claim our attention. On the single spindle variety there is not much to say; development has been intense in recent years, in fact, one is tempted to opine that it has been carried too far. Of all machine tools the drilling machine appears to have been selected as a display board for the versatile ingenuity of the engineer until we are at present faced with a most fearsome array of controls and gadgets. These on a machine which, for the purpose under discussion, will only be called upon to produce one or two different sized holes in one class of material. Some manufacturers are beginning to realise the futility of putting into a machine more than it is required to perform and a simplified product is the outcome. Pick-off gears are provided for varying the speed and feed should that ever be necessary, feed throw-out to enable spindle to be moved by hand to or from the work and a starting and stopping lever, and the machine is ready to tackle any job in quantities. Radials will also receive this attention in due course. For cylinder block work the Multi-Driller and Tapper is undoubtedly unrivalled, even for small quantities. It may still be necessary, in fact, it often is on even moderately large outputs, to use single spindle machines but there is room for Multi's on even an output of 15 per week. More than any other machine does this class call for careful planning and the balancing of the

pros and cons in the case of batch production. For instance: with an output of 5 cars per week is it better to batch the 5 or to put through 20—or any quantity between those figures? Another source for investigation and careful routing is the possibility (because of the mating holes in each component) of drilling the top of the cylinder block and the cylinder head at the same setting; bottom of block and crankcase and other locations are also obvious. Full advantage should be taken of Quick-change Chucks and Slip Bushings for Jig Plates; with these two aids to partial "break-down" and remembering that a total "change-over" can be accomplished in an average time of 2 minutes per spindle, there is no reason why multi-drilling and tapping should not be more generally used. Most drilling lay-outs call for the production of different-sized holes on the same elevation; this is looked after by the provision of an independent speed to each spindle so that each drill runs at approximately the correct r.p.m., this of course speeding up production over the old-time method whereby the speed of all had to be the speed of the slowest.

Multi-tapping is just gaining a foothold and is another instance where a safe prophecy can be given that in a few years it will be in general use. Other things being equal the obvious advantage is speedier production. One of the "other things" which at first sight would seem to nullify the benefits of quicker tapping—the time and trouble required to remove broken taps—does not arise. In fact, instead of being a minus quantity multi-tapping is decidedly positive in that tap breakages are reduced. For this reason: most tap breaakges (apart from those caused by using blunt taps) arise from the tap not being truly square with the hole. Especially is this so when machine tapping a heavy component, unless the tap is in absolute alignment with the hole it commences to cut deeper on one side, an excessive strain is set up which tends to release itself by pulling over the component: result: a broken tap. In multi-tapping this is overcome because one setting in a locating fixture definitely locates the holes in relation to the spindles and an easily cut, square tapped series of holes is the result. To get the fullest benefit from this process it was necessary to devise a means of tapping threads of different pitch whilst maintaining the same spindle (or table) travel. This has been done with an effective positive over-riding device. Where extreme accuracy is called for, or the nature of the job would possibly give rise to a refusal of the tap to start its work, a pitch lead is provided to each spindle. Another feature of up-to-date multi-drill equipment is automatic feed, either cam operated or, more recently introduced, hydraulic power feed.

Another multi-operation is the machining of valve stem guide holes, valve heads and seatings. This lies between drilling and

boring and can be handled on a heavy multi-drill or a light boring machine of the rail drive type.

At this stage it would be as well to emphasise that multi-drilling makes the actual time during which one component occupies a machine very low indeed, as an example: one plant is drilling 40 holes (26 — 3/8 in., 14 — 15/16 in.) to a depth of 3/8 in. in 9 seconds. It will be realised that to get the worth out of the investment an operator cannot be expected to man-handle a casting to any great extent at such short intervals. This indicates good conveyor and fixture design. On small outputs conveying work would be with overhead runway and hoisting tackle; if trucking is resorted to then use a platform truck. As soon as quantities justify line production a conveyor, level with the work tables, is essential, if possible have the table of the last machine in the line lower than that of the first with the others gradually descending so that gravity does the rest; in fact, why not let the supplier of the casting provide all the power necessary to carry the component through the shops by having the unloading ramp the highest point in the lay-out?!! The latest type of roller conveyor leading directly on to the table (which is also equipped with rollers) is excellent, especially if equipped with a lift jig so that when the block is in position, dowel pins are raised by means of a lever to register in previously machined holes, and definitely locate the component. Another scheme, used when seconds have to be saved, is the tram track conveyor. Here the block is placed in a fixture at the head of the drilling line, the fixture being mounted on a carriage with flanged wheels running on rails. If it is required to perform two operations on one machine, such as drilling and spot facing, the carriage has vee-ways at right angles to its direction of travel so that the component can be brought under the desired set of spindles. Of course, the fixture itself is of the trunnion type so that different faces are presented to the spindles as required.

Of the semi-special machines evolved for dealing with large outputs, that which uses standard heads built round a fixture so that four, or even five, faces are drilled at once, is interesting when one appreciates that it then only takes as long to drill anything up to a hundred holes, in the time taken to drill the deepest hole of the 100.

Of the remaining major operations the only one left does not arise with the block taken for a concrete example, that is the boring and reaming of crank and cam shaft, etc., bearings. However, as this comes into all cylinder block production where the top half of the crankcase is integral with the block, it would not be amiss to consider briefly the requisite plant. This operation is one for serious thought in order to get the ratio between handling time and machining time somewhere in the neighbourhood of the other operations. If halves of bearing and bearing

seatings were truly interchangeable this would be achieved. The author understands that at least one British firm is manufacturing and supplying to a large automobile works a split-bearing which is not mated at any stage of its manufacture. Generally, practice on both sides of the Atlantic is to bolt up the halves and machine in line. Usually a horizontal boring machine is used with as many heads or "tool driving terminals" as there are lines of holes. It is surprising that a greater development in vertical machines for this operation has not taken place, if only on the grounds of less floor space being occupied. Except in the case of small outputs a duplex fixture and a duplicate set of boring and reaming bars should be provided. Alignment should be entirely independent of the machine, therefore a quick acting fully universal coupling should be provided between the driving head and the bar.

If the bearings are "stepped" in size the cutters or reamers may remain in their bars but if bearings are of the same diameter then the tools have to be assembled after the bar is in position, this involving the use of a cutter holder which can easily be removed without disturbing its size. The author knows of a line bar installation for bearings of the same diameter with collapsible cutters. The main objection is the difficulty in keeping swarf away from the blades and consequent chance of losing size.

For sizing bearings with this type of equipment the most interesting introduction of late is a special holder carrying a diamond tool. This is on production service, keeping within a tolerance of 0.0003 in. and turns out from 12 to 15 cases before adjustment is necessary. Cutter is run at 900 to 1,000 surface feet/minute and the feed is 0.001 in. The tool works on bronze cam shaft bearings and babbit crank bearings.

The author has recently been associated with a successful experiment in using Broaches for machining bearings in line. To date some hundreds of cases have been broached, the broaches have not yet been ground and alignment and size well within the designer's requirements have been maintained.

Those are the main machines and their variations which will be used on cylinder block production. In producing any quantity over 150 a week they will undoubtedly be arranged for line production. From that quantity down to 100 a week is the border line whilst below 100 batch production seems to be resignedly taken as inevitable. Is it? The objection to the "line" method is the unprofitableness of expensive equipment standing idle. Even this is not always true but if it can be prevented so much the better. On cylinder block production three types of expensive machines are used on two or more operations: surface milling (or grinding) boring and multi-drilling. Also the first and the third are used on other components, the third oftentimes with the same layout.

excepting that some hole locations required in the block are not called for in the cylinder head or the crankcase. It should be possible to maintain " line " production on even small outputs if these " key " machines are made common to the block, head and crankcase lines. Careful planning is called for; until the shop becomes familiar with the scheme it would be necessary to be generous in time allowances. Attention would also have to be given to the fixtures so that head or block could go through on the same table and cutter setting. In the case of multi-drillers it would also be necessary to use quick change chucks, the drills for each component should be painted a separate brilliant colour to indicate to the operator which drills have to be used.

On very small outputs the " surge line " system should be developed. Operations on major machines can be made to run in the sequence milling, boring, drilling, finish milling, finish boring, drilling. If the first three are done in line and collected at the third operation that constitutes one surge, the second starting when the last of the week's requirements has passed through the first operation and the machine is re-set for performing the fourth. This admittedly is not a true line as the supply of blocks to the assembly department ceases to flow during the first half of the week but it does introduce into the machine shop the unseen discipline of line production, keeps work in progress to a minimum compatible with economic plant lay-out, provides an experience available when greater output is required and means that when developments take place the plant is suitable to use in a larger scheme.

The line drawings are of a block suitable for commercial vehicle work and admittedly are devoid of much detail. Every block being produced will vary from the example; by reducing the problem to its simplest form we shall have a good foundation upon which to build a lively discussion.

In considering the following lay-outs a week of 5 days of 8 hours each has been taken.

An output of 25 blocks a week gives a time factor of 96 minutes —therefore the true " line " system cannot economically be used. This affects the question right at the start for it will be necessary to hold the castings at the "Goods Received" end for maybe a few days.

The small quantity will hardly justify plant for heat treatment and pickling so arrangements should be made for these operations to be performed at the foundry.

Immediately castings are unloaded they should be subjected to:—

Operation 1. Finish fettle with a swing grinder or a motor driven flexible shaft grinder. Grind on top face a strip as wide as the

wheel and about 2 in. long—only remove enough metal to clean away casting "pimples."

Operation 2. Inspect casting for visible defects; gauge cylinder barrel for wall thickness; take Brinnell reading on ground strip. (Brinnell, although not an absolute measure of machineability, is of use in indicating if any particular casting is much harder than its fellows.) If Brinnell is high but casting is otherwise O.K. daub with red paint on outside of cylinder barrel.

Operation 3. Hold red daubed castings pending instructions. Upon instructions from Progress Department send forward 6 completely O.K.'d castings. Place on a bench which will be as high as and next to the table of the machine to be used on Operation 4. Table should have as far as possible a frictionless surface. Use a stacking truck for transport.

(The Storekeeper will be responsible for routing Operations 1 to 3. The technicalities of operation 2 are the Chief Inspector's care.)

Operation 4. Surface grind top, base and sides. Use rotating table surface grinder with one fixture for each operation on table. Time—15 minutes.

Operation 5. Use two Multi Spindle Drills. On the first use a two position fixture. With fixture in rear position drill 14 stud clearance holes in base; pull fixture forward, drill 8 — 1-5/8 in. tappet clearance holes and ream the four corner stud clearance holes for subsequent locating purposes. On second machine: drill and tap 26 — 1/2 in. B.S.F. holes in top; arrange one group of 13 drill spindles and one group of 13 tapping spindles.

Operation 6. Hog out bores and chamfer top of barrel. Use four spindle boring machine. Locate off holes reamed during previous operation.

Operation 7. Water test. Hold at 50lb. /sq. inch for 5 minutes. Use special rig. Then pass on to an in-line Multi. Drill valve guide holes, change tools and ream. Change jig plate, core-drill and rough out valve seating.

Operations 4, 5, 6 and 7 are the first surge of a "surge line" lay-out. A roller conveyor connects the machines. The four machines will now be available for other components. Those used on Operations 4 and 6, also the Multi Driller used on the top of the block during Operation 5 will be available for Cylinder Head Production. The Multi Driller for the bottom of the block will fit into a lay-out for crank cases and the in-line Multi used on Operation 7 can be used for tappet guide holes in crankcase and valve clearance in cylinder head. One Operator looks after Operation 4, another Operator can manage Operations 5 and 6, whilst a third will be required for Operation 7. The time factor for these four operations is 15 minutes each.

The next surge is carried out on ordinary Drilling Machines

which are arranged close to and parallel with the first surge machines.

Operation 8. Drill and Tap two 3/8 in. B.S.F. stud holes in induction flange. Use a two spindle Drilling Machine. Press in 8 valve guides, use an Arbor Press.

Operation 9. Core drill and counterbore 4 plug holes on near-side. Counterbore is 1/8 in. deep and diameter is held close for at a later stage (during assembly) a M.S. Disc is pressed into each to form a water seal. Use a single spindle Drill with a sufficiently long table.

Operation 10. Drill 6 - 3/8 in. B.S.F. Tapping Holes and 2 - 1/2 in. B.S.F. tapping holes; all on near side. Use a radial.

Operation 11. Tap holes drilled during previous operation. Use a radial.

Operation 12. Spot face stud clearance holes in base. Use two radials each with reverse feed.

This operation completes the second surge and, as in the first surge, the machines are connected by a roller conveyor. The machines used on operations 8 to 12 will be available for "batch" production of small components during the remainder of the week. Time factor on second surge is 10 minutes.

When next the line used on the first surge becomes available the third and final surge on the Cylinder Block is commenced. A time factor of 15 minutes is allowed.

Operation 13. Using Surface Grinder used during Operation 4 grind end faces.

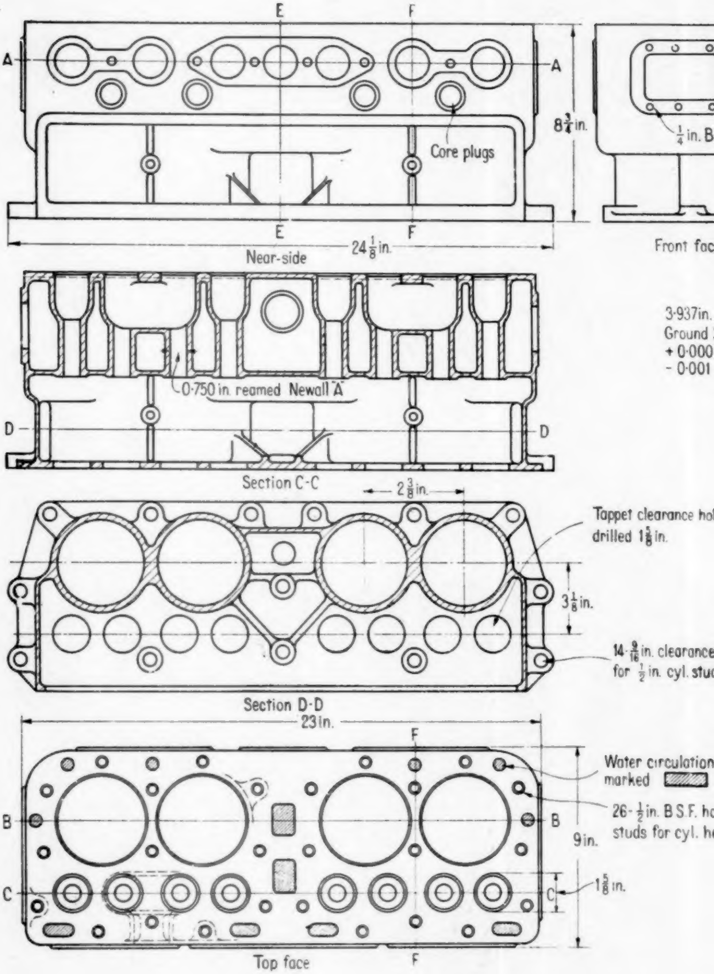
Operation 14. Drill and Tap four groups of 8 - 1/4 in. B.S.F. holes, two groups are on off-side and there is one at each end. Arrange one Multi-Driller, used for Operation 5, with two groups of spindles, one for drills, the other for taps.

Operation 15. Finish bore and float ream Cylinder Barrels. Chamfer bottom of bores.

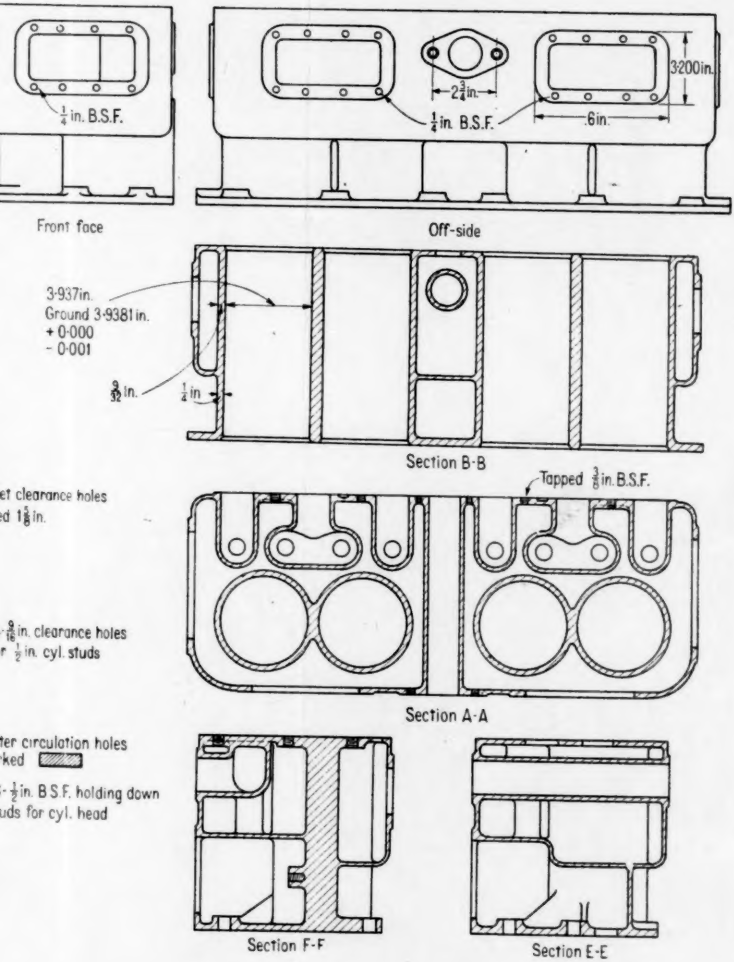
Operation 16. Using in-line Multi used during Operation 7 ream valve guides and finish off valve seats.

Operation 17. Hone bores. Use a drilling machine of rigid construction but with sensitive feed lever. Then place on conveyor for passing through a rotating arm washing machine to Inspection Department. One Operator looks after Operations 13, 15 and 16, whilst an Operator is required for each of Operations 14 and 17.

The total machine hours are 72 for the 25 blocks, an average of 2.88 hours each. To this must be added the charge for the Arbor Press used on Operation 8, also the on-cost for the Water Test rig and a proportion of the Washing Machine expense. The total machine hours are decreased by the fact that the Drilling Machine used for Honing can be used for other operations, whereas a Cylinder Grinder would be working most of the week (and engaging an operator throughout the week).



E
F
A
A
8 3/4 in.
Core plugs
E
F
24 1/8 in.
Near-side
1/4 in. B
Front fac
0·750 in. reamed Newall 'A'
D
D
Section C-C
3·937in.
Ground
+ 0·000
- 0·001
2 3/8 in.
Tappet clearance ho
drilled 1 5/8 in.
3 1/8 in.
14 - 9/16 in. clearance
for 1/2 in. cyl. stu
Section D-D
23 in.
F
Water circulation
marked
B
B
26 - 1/2 in. B.S.F. h
studs for cyl. h
9 in.
C
C
1 5/8 in.
Top face
F



$\frac{1}{4}$ in. B.S.F.
Front face
$2\frac{3}{4}$ in.
$\frac{1}{4}$ in. B.S.F.
3·200in.
6in.
Off-side
3·937in.
Ground 3·9381 in.
+ 0·000
- 0·001
$\frac{9}{32}$ in.
$\frac{1}{4}$ in
Section B-B
Tapped $\frac{3}{8}$ in. B.S.F.
et clearance holes
ed $1\frac{5}{8}$ in.
$\frac{9}{16}$ in. clearance holes
r $\frac{1}{2}$ in. cyl. studs
Section A-A
ter circulation holes
rked
$\frac{1}{2}$ in. B S.F. holding down
uds for cyl. head
Section F-F
Section E-E

The number of separate machines involved is 12, again excluding Arbor Press, Water Test, Washing Machine and Swing Grinder used on Operation 1. These are all available during non-operation on Blocks for Cylinder Head, Crankcase and Gear Box production or batch work on small components; any idle time should be debited against the Bonus account of the Planning Department!

Direct labour amounts to 64 hours for the 25 blocks, an average of 2.56 hours per block. To this will have to be added labourer's time on Operations 1, 2, and 3, also labourer's time on Washing Machine. Inspection in Stores and View Room will be a general machine shop on-cost.

Indirect labour on the "floor" apart from usual millwright's labourers and sweepers, will consist of a charge-hand for the 12 machines, a perambulating inspector and tool-room labour. Obviously, they would not be entirely on Cylinder Blocks. The only progress paper work would be One Works Order Card perforated into three strips. Each strip would state quantity required (usually 25) and bear the same distinguishing symbol or number. Space would also be provided to record "Rejected at Operation . . . ; see P.I.'s Report No. ......" Strips would be marked from the bottom up, Surge 1, 2, and 3 respectively. Each strip would indicate "Commence on ...... at ......" and Surge 3 strip would have on the back room for Final Inspection Report

As explained under Operation 3 the line is started with 6 castings; the chargehand watches this supply and as soon as it drops to 2 he rings a push bell which communicates with the Storekeeper who immediately sends forward another 4; this is repeated until 25 have been delivered as required. An hour before the first surge is due to start the chargehand notifies the Toolroom who despatch from their stores necessary Fixtures, Tools and Gauges, together with a box of drills, taps and reamers which experience has shown likely to need immediate replacement. This box has compartments for each operation and is the sole charge of the chargehand who alone can authorise the change of tools. Fifteen minutes before time to commence the surge the Toolroom foreman sends a man to assist the chargehand set up each operation, the operators acting as helpers. T/R. foreman is notified when a surge is completed and arranges to collect all Fixtures, Tools and Gauges. The Gauges for each operation are placed in a convenient rack and are only used by the P.I. or the chargehand. The Chief Inspector issues an Inspection Card for each operation, this is stamped by the P.I. with a watchman's clock each time he inspects that operation. If a fault is discovered it is then easy to calculate how many blocks have gone forward since the last inspection and to make arrangements to check them up.

With an output increased to 250 per week the Production

Engineer would undoubtedly get into contact with the Designer and ask for some modifications. Let it be assumed that his wishes have been met to the extent that the sides need not now be finished by grinding and that the bosses of the holding-down stud holes are brought forward so that they can readily be milled; those tucked away in the centre being dispensed with by a general modification in design.

Some of the Machines used to produce 25 a week will be found in the re-organised lay-out for ten times the output. A true line system will be possible and pickling can be handled even if heat treatment is still done at the foundry.

For storage nothing better than the Morris spiral chute has come to the Author's notice. With these few remarks as introduction the suggested operations for the medium output will be outlined.

Operations 1 and 2, as previously described, excepting that as soon as unloaded the castings are placed on a roller conveyor and progressed along to the third operation.

Operation 3. Pickle. Reference is again made to Morris methods as being suitable.

Operation 4. Rinse and hoist to top of spiral chute. To combine these operations the Author puts forward as a suggestion that the hoisting tackle travels through a vertical tunnel in which is arranged at suitable intervals jets of heated neutralising compound. Place casting on chute which will lead to the machine used for the next operation. To attain an output of 250 a week a basic time of 9 minutes 36 seconds has to be observed, or, on an 85 per cent. efficiency basis 8 minutes 9 seconds. Therefore, from operation 5 onwards this factor must be carefully kept in view.

Operation 5. Mill top, base and near-side of block. Use a Reciprocating table Plano-Miller; side heads machine the top and base and the head on the cross rail mills the side.

Operation 6. Mill ends and off-side. Use a standard Plan-Miller. A head on each side machines either end and the cross rail carries three cutters, one for each of the joint faces on the side.

Operation 7. Drill stud clearance holes in base, pull fixture forward, drill tappet clearance holes and ream four corner holes.

Operation 8. Hog out bores and chamfer top of barrel.

Operation 9. Water Test.

Operation 10. Drill and tap 26 holes in top. Perform operations in groups of 13.

Operation 11. Drill valve guide holes, pull fixture forward, core drill and rough out valve seats.

Operation 12. Drill 6 - 3/8 in. B.S.F. Tapping holes and 2 - 1/2 in. B.S.F. tapping holes in near-side. Pull fixture forward and tap.

Operation 13. Core drill and counterbore plug holes on near side; use a single spindle drill.

Operation 14. Drill and tap 16 - 1/4 in. B.S.F. holes in off-side and 8 ditto in each end.

Operation 15. Mill holding down lug faces. Use two vertical mills.

Operation 16. (a) Ream velve guides holes (a sub operation of pressing in valve guides is then performed). (b) Ream valve guides and finish cut valve seats. Imagine that the operator has just completed the machining cycle; he first pushes the component from (b) further down the line, replaces it with casting from the platform which carries the arbor Press, pushes casting from (a) on to the Arbor Press table and then replaces it with component received from operation 16. One pass of the spindles then reams the 16 holes.

Operation 17. Grind top and base. Use Rotary Table Vertical Grinder.

Operation 18. Semi-finish and ream bores also chamfer bottom of cylinder barrels. Gauge bores and mark with chalk amount to be removed by hones.

Operation 19. Hone. Use a hydraulically reciprocated machine. Refer to chart and run hone in bore for exact number of seconds indicated on chart. Place on conveyor leading to washing machine at the other end of which is located the Viewing Dept.

Machine hours on this lay-out amount to 600 for the 250 blocks, an average of 2.4 per block. To these figures should be added the charges for the equipment used on operations 1, 2, 3 and 4; the Arbor Press used on Operation 16 and proportion of the Washing Machine expense. This machine will handle a cylinder block casting in about one minute and, for an output demanding 250 engines per week, should be common to several component "lines."

One Operator looks after operations 5 and 6; one Operator handles 7 and 8; another is sufficient for 9 and 10; another for 11 and 12; one Operator manages 13 and 17; one is required for 14; one is sufficient for the two machines (a doubled time factor) on Operation 15 and he can also take care of 18; whilst 16 and 19 each demand individual attention.

Direct labour totals 360 hours for the 250 blocks, an average of 1.44 hours per block. To these figures must be added part-time labour on Operations 1, 2, 3 and 4 also a proportion of labourer's time on Washing Machine

The indirect labour will be very much as for the 25 per week lay-out, excepting that the charge hand and perambulating inspector will devote the whole of their time to the line. The charge hand will be supplied with the box of replacement tools, as previously, but it is now suggested that all cutting tools are changed every dinner hour and evening; it being better to anticipate "break down" than to suffer it. The charge hand's title will be prefixed "working" —, he will be available to step into any breach caused by the temporary absence of an operator and will be imme-

diately responsible to a senior charge-hand who would have under his care two lines. It is suggested that this scheme makes a good provision for an understudy to each official and eases the "break" when promoting a man from the shops.

When an output of 2,500 per week is called for it will be obvious that more modifications in design will have taken place; the grinding of any of the faces will not be called for and the block will be cast with the top half of the crankcase. For purposes of comparison the latter will be ignored and it has been assumed that the only alteration at the bottom of the block is that the stud holes are brougnt further out to enable spot facing to be done from above. An output of this magnitude calls for a time factor of approximately 59½ seconds but instead of reducing this to allow for an efficiency lower than 100 per cent. it is proposed that a line capable of handling 250 blocks should be installed by the side of the main production plant. This is well nigh essential for various reasons. A 10 per cent. increase in demand can be looked after by running a double shift in a minor portion of the plant. The accumulation of hard castings can be put through with tools, speeds and feeds adjusted to meet requirements. The results of experiments in foundry mixtures and methods can be watched and tests of new steels and tools carried out under actual production conditions yet without disorganisation of the main plant.

Obviously the time factor will demand more than one machine for each operation; for instance, the best milling time factor within the author's knowledge is 2 minutes 20 seconds per block. However, before considering the machine shop the receipt of the castings and their delivery to the machine must be considered.

Operation 1. Unload and place on an Automatic hoist to lift to top of a spiral chute. (The bottom of this chute is in the shop where Operations 2 and 3 are performed and its capacity is just sufficient to act as a buffer between unloading periods.) 4 labourers.

Operation 2. Take casting from bottom of chute and place on on roller conveyor. finish fettle and grind "Brinnell strip." For this operation there are three lines of conveyor and three operators.

Operation 3. On the same conveyor track inspect casting, and place on second conveyor chute. (This chute leads to shop where Operation 4 commences.) Three operators.

Operation 4. Pickle. Because of the length of time castings should remain in the solution the 8 hour day is not practicable; a 24 hour day is proposed. Pickling bath is 50 ft. long. Castings are suspended three abreast from a power driven over-head runway travelling at 10 ft. an hour. Rows of hooks are placed 15 inches apart hence 24 blocks enter the bath every hour. After leaving

the bath the run-way continues to carry blocks forward another 5 ft., giving them ample time to drain. As the runway discharges the load it is automatically picked up by an elevator which carries the blocks through a vertical tunnel where they are subjected to sprays of heated killing solution. At the top of the tunnel the castings are automatically discharged into yet another chute which has its base resting in the machine shop. Six operators in three gangs of two each will be required. Each man would work one hour of this shift alone.

Operation 5. From base of chute in machine shop take a casting and place it as required on one of the gravity conveyors leading to the first machines. One operator. (8 hour day.) There will be four of these machines. Three of them concerned with main production and the fourth the first machine of the 250 per week buffer or experimental line. Only the main production will be considered.

Operation 6. Mill top face. Three Differential Rotary Milling Machines taking roughing and finishing cut. Three operators. A casting every 59 seconds.

Operation 7. Mill Base.

Operation 8. Mill Near-side.

Operation 9. Mill Off-side.

Each of these operations use 3 machines similar to those used for **Operation 6;** require the same number of operators and give the same time factor.

Operation 10. Drill stud clearance holes in base and ream four corner holes. One Multiple Drill to give required time factor. Casting is slid on to table off Roller Conveyor (which is the same height). Approximate location is off strip on front of the table and another on the right.

As hydraulic feed is applied, suspended jig plate is lowered and locating pins definitely locate plate on casting. When head has automatically retreated at 80 inches a minute casting is pushed back to approximately locate against a strip at the rear and another on the left, another casting is pulled off the conveyor to take its place, feed engaged and the cycle of operations continued. Drilling takes place in front of table and reaming at the rear. After the first pass of the head one casting comes off drilled and reamed at every pass of the head.

Operation 11. Rough and finish mill ends. Use two Drum Continuous Millers. Two operators. Each Machine carries six castings and delivers one casting every 1 minute 52 seconds.

Operation 12. Rough bore barrels and chamfer top of bore. Use four 4-spindle boring machines. Two operators.

Operation 13. Drill 26 — 1/2 in. B.S.F. tapping holes in top. Use a Multi with an arch jig and fixture built on to the table. Conveyor runs right through the arch and component is

located by dowels being raised with a cam into holes reamed during Operation 10. Hydraulic feed.

Operation 14. Tap 26 — 1/2 in. B.S.F. Tapping holes in top. One operator looks after operations 13 and 14.

Operation 15. Using a multi, drill valve guide holes and spot face stud clearance holes in base. Hydraulic feed used. When casting is taken from fixture turn on its side feet to the front, off-side uppermost.

Operation 16. Using a horizontally opposed twin head multi, core-drill and rough cut valve seatings in top and drill tappet clearance holes in base. One operator looks after operations 15 and 16.

Operation 17. Drill — 161/4 in. B.S.F. tapping holes and 2-3/8 in. B.S.F. tapping holes in off side.

Operation 18....Tap the 18 holes in off-side. One operator looks after 17 and 18. The conveyor just beyond this fixture has a Vee, the sides of which are about half the length of the casting; this facilitates turning over to bring near side uppermost.

Operation 19. Drill 6—3/8 in. B.S.F. tapping holes for manifold studs, 2 — 1/2 in. B.S.F. tapping holes for side cover studs and counterbore the 4-1.1/4 in. core plug holes. The 6 holes break through before the 2 side cover holes and the counterboring commences; the counterboring tools being the last to engage the work.

Operation 20. Tap holes drilled on previous operation, same operator.

Operation 21. Drill and tap 8 — 1/4 in. B.S.F. holes in front Face. One Machine, One Operator.

Operation 22. The same as 21 only on Rear Face.

Operation 23. Ream valve guide holes, ream valve guides and finish cut valve seats. Set up as for Operation 16 on the 250 a week lay-out is used. In the case of 2,500 a week the sub-operation becomes a separate operation. One operator.

Operation 23 a. Press in valve guides. Use a compressed air operated press. One operator.

Operation 24. Finish bore, ream and chamfer bottom of cylinder barrels. Use four 4-spindle machines each carrying four blocks at right angles to the line of spindles. Two operators.

Operation 25. Hone. Use two Multi Hones, Hydraulically operated. Run hones for one minute. Two operators.

Operation 26. Inspect bores and mark (if necessary) for rectification on single spindle honing machine. One operator.

Operation 26a. Rectify bores — use operator from 26 or a spare man as necessity dictates.

Operation 27. Washing, use two machines. Operator from 26 puts O.K.'d castings on conveyor; viewer take it from other end of machine.

Including the Press for the valve guides and the spare single

spindle Honer for rectification a total of 40 machines is used in the machine shop. This gives an average of 0.64 machine hours per block. The machine shop direct labour averages 0.48 man-hours per block. Indirect labour will provide for three spare men to guard against delay caused by sickness or temporary absence of operators; two under-chargehands, two perambulating inspectors and one charge hand.

That concludes a rough outline of the main differences which are to be found in lay-out for different outputs. In each example there is room for improvement; as an instance, the milling lay-out in the 2,500 scheme needs consideration in the light of improvements in grinding machine performance which have been given prominence since the lay-out was envolved. However the milling machines used on Operations 6, 7, 8 and 9 have something in hand; operation 6, 7, and 8 can be performed in a time factor of 47 seconds and operation 9 can be reduced below that. Further, swarf from milling machines can be cleared away more easily and fetches a better price than the sludge from the grinding process; two important points when large outputs are being considered.

In conclusion, the Author would again stress the fact that many arguments have not been fully developed and many details have been skipped; partly because time presses, mainly to make the discussion as full and as free as possible.

Finally; thanks are accorded to those friends on both sides of the Atlantic who have supplied various fragments of information, also to the author's employers for the gift of a stenographer's services, but it is wished to emphatically to state that they are not in any way responsible for the facts, suggestions or opinions expressed in this paper; the enterprise being purely an individual effort on the part of the author

Discussion on Mr. Mantell's Paper.

THE PRODUCTION OF CYLINDER BLOCKS IN QUANTITIES OF 25, 250 and 2,500 PER WEEK.

February 25th, 1927.

MR. HUTCHINSON: This is a paper that really requires a lot of consideration, particularly before one can develop any discussion on the relative merits of the layouts for the three quantities of cylinder blocks mentioned. One of the principal difficulties with which the production engineer is, of course, always faced, is to devise cheap production methods for small quantities. We must admit that given a large output, given the capital for putting in the right layout, such as the layouts mentioned in the paper would naturally demand, then it is not a very difficult matter to employ quite a lot of apparent ingenuity in the manufacture of special purpose machines, but where the real ingenuity of the production engineer should be employed, is in producing small quantities, or show how to produce small quantities on methods which compare favourably with the costs of larger quantities. I think that is the most important point, because it is only by that means that it enables the smaller manufacturer to compete in the financial conditions which reign in this country, and develop into a large industry, and that is a point to which I think the production engineer should always give very great consideration. So far as the notes I have made here are concerned, I think I will use them if necessary after the general discussion has taken place.

MR. WEATHERLEY: I have thought a good many times I was going to slate Mr. Mantell, but he has gone on and I have forgotten all I was going to say, but there is one thing that struck me, during this paper, and that is the change of design three times to assist the altered layout. Had he kept to one design and catered for the man who is producing 25 I think he would have been of great help, because as our President has said, anyone who has large quantities to produce has automatically the money to lay down the special purpose machinery. Well now, 25 a week would give a production of an hour and a half for six cylinders if worked out on one machine in particular. Before the morning is over production has finished. The machine mentioned on 25 a week would not run more than about 3 days a week at the outside. It is a very expensive machine, probably the most expensive machine of the lot. The man who is producing 25 has

got to sell his car at a bigger price to meet his capital charge, and it does come to a point as to whether simple standard machinery is not more economical for the man with the small production. We had a paper here twelve months ago from Mr. Armitage, and I do not think anyone who has been round his works can deny that more use is made of standard machinery in quantity production than his.

The next machine that he suggests in the 25 a week is the multi-spindle drill. In my own actual experience, multi-spindle drills in small quantity production are not a success at all. It is a long time ago since I was in the production shop, but I do not go about with my eyes shut, and I find that the operator says "Phew! I am getting tired.. I have got to change this all again after about two hours." That is what a multi-spindle drill means when you get 25 a week and the operator has to "break down" frequently; in my experience the multi-spindle drill stands for four days a week quantity production. There is one point which struck me on quantity production. He gave details of the number of operators required, and stated that one operator should take charge of, I forget the number of operations, but there were 3, 4, or 5 other operations in between him and his stations on a line job. I would like to be told whether an operator has got to run from one end of the shop to the other to perform those operations. I am not quite clear on that. I will end by thanking the author for his paper because I am sure he has devoted a lot of time and trouble to it for our benefit.

MR. MANTELL: So far as the change in design is concerned, I did not change it as much as it would have been changed in practice. I had to get comparative times, but I think the steps I took were quite legitimate. The idea was to give a comparison between different outputs, and one must recognise that the cylinder block in a car produced in lots of 2,500 a week bears very little resemblance to the one produced on the 25 per week layout. Had the paper been only on 25 per week we could have elaborated quite a lot, but the object of the paper was to point out the differences between the various quantities which are mentioned in the title. Concerning special purpose machines there is only one mentioned, and even so that is only a semi-special purpose in that it employs standard heads arranged in a different plane from which they are normally found, otherwise every machine there is a standard machine.

Mr. Weatherley is afraid of seeing the machine tool standing idle whether it is earning money or not by doing so. I would much sooner see 10 men in the shops and five machines idle most of the week than I would see 30 machines and 30 operators being worked to death. The fear of idle machinery is an attitude to be combatted in this country. I am surprised to

find it expressed in the Production Engineers, I thought we only had to battle with the people who hold the money strings. On the multi-spindle drilling machines, you say these are not a success on small outputs. I have seen them successful on quite small outputs, and the breakdown would not come as frequently as you say it would. Admittedly, the change-over of components would take place in about five hours. I expressly stated in the paper that the same layout could be used on another component by merely changing tools and not changing the spindle set up. In a well-planned shop using a minimum of operators which are engaged at as low a rate as possible (that is, skilled operation) the breakdown is not done by the operator at all who merely assists whilst it is being carried out.

You mention the travels of the operators. Some few years ago (which makes it almost ancient history) a paper was read before several branches of the Automobile Engineers describing the production methods in a progressive British factory. The other day I was looking through that paper and found that an operator's duties on that machine gives him six operations to look after. One of these operations is performed on a four minutes cycle and the others at eight minutes.

I do not think that any operators have been killed through that method of working, and I have not heard of any strikes in that plant.

Mr. Weatherley: I would like to correct some of my remarks. When I referred to special purpose machines I was not really referring to expensive machinery. The first machine cost £1,000. In fact, a good many of them did. That is one point I wish to correct, but there is another point which arises in my mind since my question was answered. A number of operations require a radial drill, some of them being placed two or three in a line. Using a conveyor system means another radial drill, and as I tried to keep my remarks to the small production, it means another machine, and 25 cars a week do not justify a lot of machines because of the change of design every twelve months and consequent change of jigs, therefore I still maintain that anyone producing 25 cars a week has got to use standard machinery and as little as possible.

Mr. Mantell: When a man starts manufacturing 25 a week, unless he has a terrible system he does not have to stay at 25. The great thing that is noticeable in any machine shop layout in this country is that it was started off with a nice equipment of standard, inexpensive tools to produce 25 a week. Not all at once but probably in jumps of five. production increases to 50. and still this inexpensive equipment. It is then found that the radial drill is full up, so another radial drill is put down; it is found that an ordinary type of miller is full up, so

another miller of the same type is put down. Consequently, when fifty a week is reached, a tremendous amount of money is sunk in whatever sort of machine tools that were originally installed. I think that it is an axiom that when a company is first formed it is more ready to spend than later in its existence. The directors can then be persuaded to spend money on machines, being in the first flush of enthusiasm, but afterwards they quibble about it quite a lot, and I do earnestly and very seriously suggest that if anyone is contemplating putting down plant for a new company for an output of 25 per week, they put down plant which can be used for a 50 car layout with very little additional expense. Most machine tool plants in this country have first happened as I have described; they go on with a radial put in here, a single-spindle drill there, and so on, and in the long run the whole thing is almost a South Kensington Museum, and is labouring at a tremendous labour charge.

Mr. Sykes: I think I can speak more about the discussion than about the paper. To my mind it is too huge, so that one almost forgets what was said. For this reason I should have liked the paper to be about half the length it has been. I am very sorry indeed that we had not the opportunity of having a paper sent to us so that it could have been studied before we came to the meeting. There is a lot in what our Chairman said, that is, we have to consider our output. What we have to do in England at the present time is to convince motor car manufacturers, especially the directors (I think Production Engineers are already convinced) that the question of whether you can get your week's output in two days, does not matter. At any time you want to double up you have got the machines to do it in on the same small space.

Now I should like to get on to one or two points regarding the drawing of the cylinder. The first thing I said to myself, "Mr. Mantell has picked about the easiest cylinder it is possible to get hold of." The man who invented this cylinder must have been a friend of the machine shop. It is not unlike the 15.9 of the Humber which certainly was one of the best cylinders ever produced from the machine shop point of view. I was rather surprised to hear him put forward that he considers that the milling of cylinders is a better proposition than grinding. Possibly in my ignorance I disagree with him, but I do disagree if he maintains that he can get cylinders with the least amount of machining allowance which only want cleaning up. The cost of cutters to clean it up is going to be enormous. I cannot understand those who are not pickling castings but I have not met anyone yet who is doing both annealing and pickling. In speaking of special purpose machines for a large output per week.

one must not forget this, that they have got to be running the whole time. If one operation or one machine fails what is to be done with those that precede it, and what is happening behind. Reverting to grinding versus milling. Personally I favour grinding, and I should imagine the machine ought to pay for itself on the cost of cutters alone. Just imagine a plano miller or any type you like, what is going to happen when one comes across hard spots? You say anneal, if you do not anneal, what is going to happen when you do come to hard spots? I guarantee that in two years' time I could pay for a grinding machine that cost £800 by the saving on what cutters alone would have cost, on a milling machine. Another interesting thing I have not seen in this country; that is any firm producing 2,500 per week. Is it real practice or is it simply on paper?

Mr. Mantell: Every bit of it is real practice.

Mr. Sykes: Is any one doing 2,500 in England?

Mr. Mantell: No, but we can learn from other countries.

Mr. Sykes: You did speak for quite a long while on honing. I have not seen a successful honing machine yet. I was talking to a general works manager of one of the most up-to-date plants in England, and he told me that he gave honing a three weeks' trial in his own works, and the suppliers of the machine could not hone a cylinder in four hours. Two years ago he worried my head off about honing. Now he has tried it he thanked me for keeping it out. He told me that it took the suppliers two hours to rehone a bore and they even asked him if he would grind the bores before they honed them. If you take me to see bores honed at the rate you have told us this evening I shall be very much indebted to you. Will you tell me this? If you have got a cylinder block, either two or four, and the space in the centre of those bores is not correct, will your honing machine put it right? I say "No." You can only follow the bore, and if you come to a hard spot, what is going to happen? I have never been to a meeting yet where anyone has talked about broaching. I quite agree with your remarks about the preliminaries. I have tried broaching and the first thing I was up against was the hardness of the material. We got a very fine finish, but with the webbing up and also the unsupported distance, by the time we got three-parts through—crack! and we became very discouraged.

Mr. Mantell: I am very pleased to find that Mr. Sykes does agree with so many things that I say, and also to find that he is very friendly towards the man who designed that cylinder block, which shows that there is a better spirit between the shops and the drawing office than used to be in evidence. I did not say that milling was better than grinding. I said that under present conditions milling gave quicker results. I also stated grinding was handicapped by the fact that it is called upon to remove the

milling allowances and it is not given the benefit of close castings which grinding permits. Right at the end of the paper I said that the whole milling layout of the 2,500 per week would have to be very seriously revised in the light of a new machine which has been introduced within the last 2 or 3 weeks. Personally I think grinding is coming in. I am on the side of the grinding people, but in presenting the paper I tried to present the facts as I found them, not as we hope them to be. You mention that there is no money for special machines. I am afraid we shall have to refer to Morris. He has had sufficient faith to put down the money, and having done so has made a profit. That is a very big point to bring out; unless you spend money you cannot make a profit. A few firms in this country are spending money on equipment, and unless the general maufacturer does the same thing I am afraid he is going to be squeezed out very quickly. You ask: "What happens when there is a breakdown on the line production." If you fail to make any provision, of course the whole thing stops, which suggests that you should make provision. I would suggest, casually, that when an operation breaks down the prior operations continue and the components stacked by the side of it ready for the next breakdown. If you do not get enough breakdowns on your line to provide a buffer I would say that on a 2,500 a week output you will have a firm large enough to have attached to them several apprentices and students. We believe apprentices and students a nuisance in the shops, yet realising that, we have got to provide them with some experience. I would suggest that a lot of experience could be obtained in a separate shop which can be used for rectification purposes. If not rectifying they should be manufacturing blocks to put into different operations. For instance, let them take a block through to operation 15, it could then be transported to the production line. I would say that to provide sufficient reserve for a line of that description you need only tie up about 250 blocks, a tenth part of a week's output, which is not a very expensive insurance against breakdown.

MR. SYKES: You said 250, you have just been quoting 2,500, and if you have a breakdown in a line it is going to take you a couple of days to make them up again. It is going to be a frightful stacking up. Do not forget that to keep your line going you have got to have some stuff in your rought stores to feed on, at least, the same amount as goes through the finish stores. I do not know how you are going to substitute another machine to cope with the same rate of production unless you have a duplicate of each one.

Do you not think it is possible to have multi heads to give you the same results as multi drills at a less expense and less time of setting up, and would it not be less expensive on

small outputs of 25 and 50 a week? I do not think you would change a multi-drill in less than 3 minutes per spindle from one set up to another. Take 50, never mind 25, of a part which has six or twelve holes in it; you can drill them on a multi-drill in about two hours. Your setting up time is going to be as long as your operation time. I am strongly of the same opinion as Mr. Weatherley that at the present time I am able to demonstrate it possible to drill with a single spindle as quickly as with a multi taking into account the setting up time.

MR. Mantell: When I mentioned 250 a week I referred to that as the amount of material you would have tied up by providing buffers on 2,500 a week output. If a machine seriously breaks down, whether you are on line production or batch production, it breaks down,, and you have got to wait. We are not as rich as Ford, who changes over a complete machine tool, takes it out, and puts another one in, in about an hour. He has gangs ready for that, but one would have to have a very big output to justify it. Well you would stop, and that would be the end of it. The only thing is to make provision against serious breakdown by a plant maintenance scheme. Where it is only a breakdown of tools and cutters, which is the most common form of dislocation on a line layout, then I say that the 10 per cent. buffer which I casually outlined will look after your requirements. I still think the insurance is fairly cheap.

As far as multi-heads are concerned against multi-spindle drills, the multi-drilling machine can be changed over to deal with all sorts of centres between holes, whereas with the multi-head you are pretty well tied down.

MR. HEY: Not with adjustable heads.

MR. MANTELL: Not with adjustable heads, of course (I would like Mr. Hey to add his comments to this) but even so a multi-head is limited. If you have got a lot of drills in a multi-head you have got to have a very big machine to drive those drills, and by the time you have got all—a "beefy" machine, a multiplicity of heads (with a limited amount of elasticity) the cost is not much below a modern drilling machine.

As far as the setting up time being as long as the operating time, I do not think that matters so long as the two together are less than drilling with a single spindle. If you are going to drill in an hour, and set up in an hour, that is two hours, but by doing that you supersede four hours of operation, then I consider the multi begins to pay for itself, and with a multi the operator does not suffer so much fatigue as with a single spindle..

MR. HEY: I did not intend to speak on the paper unless it was to ask one small question with reference to the remark of drilling and tapping on a multi-spindle machine at the same time. That is the way I interpreted it. 26 holes were drilled and pushed

back on the same machine, and 26 holes tapped, the two operations taking place at the same time.

MR. MANTELL: You drag the component forward under another set of spindles.

MR. HEY: You said that these two operations after the first operation were taking place at the same time, that you were getting one complete cylinder drilled and reamed at the same cycle.

Regarding the question of drill heads and drilling machines, this is a complex subject. I am making multi-spindle machines and multi-spindle heads. Analysing the conditions required, I supply special multi-spindle machines, which I consider give better results than heads. Take the case of a small output of cars, I supply small multi-spindle machines. I have supplied a well-known American firm with multi-heads that have quadrupled the output of any multi-spindle they have had. I have replaced all their American machinery with multi-spindle heads alone. Taking connecting rods, with a multi-head on a standard machine they are averaging 650 rods drilled and reamed per day. Regarding the boring, and so forth, I have put in multi-heads for the same purpose. The cost is 2¼d. for the finished rod—that is the complete labour cost with high wages. It is rather difficult to say whether a drill head is better than a multi-spindle machine. I think one has to decide by the conditions that are in the shops. Regarding the multi-spindle heads, they are made in all types. One can make them with adjustment for spindles with 5/16 in. centres with 3/16 in. drills, and I have made heads 6 ft. in diameter for firms in this country, and after boring they perform the drilling operation without disturbing the part. That is on marine engine work. I think it must be decided by the conditions.

MR. MANTELL: Mr. Hey's remarks confirm my own experience on the subject. I would like to ask about the heads put into that American firm. I have quite an open mind, because I am concerned, as you are, with which is best for each particular job. But was the greatly increased production at this factory due to the head or due to the fixtures which you made at the same time? I cannot see that any machine, if it is multi-drilling, is going to drill any quicker than another one. Providing each have good drills and plenty of "beef" behind them, the drilling times should be the same. It may be that you put in fixtures at the same time which were an improvement on those used with the multi-machines.

With reference to Mr. Sykes' remarks regarding honing, I should be very pleased to arrange for him to visit one firm in the London district with whom I am very well acquainted, to gather their experiences in honing, and there is another firm in the Birmingham district that is using a well-known honing machine with very great success. That firm in particular evolved their own

hones. They knew the operation was a good one and they decided to get down to it. They spent two years doing so, and having got down to it they scanned the market, and have now put in standard machines and standard hones, that is, proprietary articles.

MR. HEY: With reference to the rods, the complete machines and jigs were put in by an American firm. After these had failed for various reasons, multi-heads of American manufacture were put in and it was considered that if a head lasted six weeks it earned its keep, so they replaced those heads every six weeks, I understand. I came on the job, and put in fourteen heads of different types, and one of those heads, complete with jigs, worked eighteen months without any repairs. I had the first four back about a month ago. I am told that that first head did 149,000 rods without any time spent on repairs. Waste of time with breakdowns is an important thing, and knowing the conditions of the high tensile steels they were using, I put in extra heavy duty heads, considerably stronger and heavier in every respect than the American product. Any standard machine can be used. If a machine breaks down they can take it out of the socket and transfer it to another, and in five minutes they are away with it.

MR. MANTELL: That bears out the necessity of studying the job on the spot.

MR. WEATHERLEY: I have been recalling some of my own experience of grinding in days gone by, and am in agreement with Mr. Sykes that grinding will not knock milling "into a cocked hat," providing you allow sufficient material to be removed. Regarding grinding of bores, I do not think that there is any method which will beat cylinder grinding for a perfect bore. I think a little extra time on a cylinder bore is justified, because it is the heart of an engine. If a very quick roughing operation is taken, and jigs and fixtures are accurate, and a subsequent removing operation to within a nominal ten-thousandth for size, I think (with a fairly average operator) that you can get them out at about 8 minutes a bore, that is, providing the previous operations have been accurate, and the bore is in line with the face. If an operator has to keep on packing his face to clean up the bore, obviously he is going to lose time. Taking everything into consideration, and assuming that the bore comes to the grinding machine reasonably accurate, I think if you get an average of three blocks, or a little under, in an hour, that the results are more than justified. I claim that with all these new operations, there is a certain amount of time lost in preparing the cylinders for them, and the results when the car is in use, somewhat explained why one engine runs better than another. This is my last experience on cylinder blocks. They were cylinders designed for broaching, but it was not a success. We tried reaming, we tried rolling, which was also not a success, and we came

back to grinding, and at grinding we stopped, and I still maintain that to get perfect cylinders they must be ground.

MR. MANTELL: I am sorry to find you are so reactionary. Let us take it technically. In grinding you have a very small wheel on the end of a long spindle; even on the best machines this resembles a flexible shaft. You have got just line contact with your cylinder bore, and I do not care who does the job—an excellent man, the best you can find for cylinder grinding—if you put that cylinder under a microscope the hammering effect of the grinding wheel due to its smallness and flexibility of the spindle, is quite apparent. Again, by using an abrasive agent which has got a line contact, you dig off the metal. It does not appear so to the eye. In fact, the many small facets make it appear better to the eye. A "fuzziness" is set up by grinding, whereas with honing the "fuzziness" is kneaded in and a much smoother surface is obtained; this can be demonstrated easily.

As far as time is concerned, you say the bore is the heart of the engine, and I would certainly disagree with a process that merely saves time at the expense of efficiency in that very essential part of the block, but in honing you have got a process which is better technically and better commercially, because you perform the operation in much less time, and get much better results.

You refer to one engine running better than another. I know your taste in motor cars tends to "Buy British and be proud of it," and if it has been your experience that one engine runs better than another, that is a fact that rather leaves one to conclude that grinding has not been satisfactory, because until the last month or two there have been few engines produced in this country that have been honed. It can be demonstrated (I say that with perfect confidence, and am prepared to attend any demonstration you would like to arrange) that a honed cylinder is better than a ground cylinder, technically, even if you spend an hour on the grinding of the bore.

MR. WEATHERLEY: The engines I referred to were the engines we were experimenting with, with the rolling, and broaching, and grinding, not the ones I have preference for at the moment. I am quite willing to admit that honing is a good operation, but I still claim that if it is necessary or essential to get a good bore you must grind beforehand to get a perfect bore.

Now referring to your chipping operations, that results from an incorrect wheel. A correct wheel will give you a perfect face, and my mind goes back to the production of a motor cycle engine cylinder, 8in. long, and approximately $3\frac{3}{4}$in. in diameter. We left an average of 0.012in. that was taken out in three cuts, and the finishing cut running twice up to the bore, at the rate of 12 cylinders an hour. I admit the operator was good, but that

is what should be done in grinding a cylinder, and we had no flats on them, they were perfect cylinders.

MR. MANTELL: To the naked eye. Not under a microscope.

MR. WEATHERLEY: I know it is possible to get something better if you like to spend the time, and go to additional operations, but commercially they were excellent, and quite satisfactory to 95 per cent. of the motor car manufacturers.

MR. MANTELL: In discussing honing with any engineer in this country, when he becomes a convert (after a very long time), he still maintains that it is necessary to rough grind and make the honing purely a finishing operation. After going into the results which have been obtained in other countries and examining the process generally, I did not agree with that. I still think that the best way is to hog, then at a subsequent operation line up with a single point tool, then ream, and finally hone. Grinding does not come into it at all.

Some very good friends of mine in this country tell me they are rough boring, reaming and then honing; their production being five 4 cylinder blocks finished per hour. That is something that does happen, and is actually happening to-day, in this country. I still think they ought to float ream closer to size, but they are quite satisfied by getting down to 3 to 5 thou. Incidentally, their running in time is now half an hour shorter than it used to be with a ground cylinder.

A VISITOR: Can I ask Mr. Mantell if he has any evidence of firms using grinding prior to honing.

MR. MANTELL: I believe that Cadillac and Lincoln used to do it. I am told that Cadillac are not doing it now, but I have not had any information about the Lincoln lately, but both are very high quality cars in which perhaps undue regard is paid to finish. I do not think it is necessary to rough grind, not even on a high grade car.

MR. HUTCHINSON: I am not going to say anything about honing. I have heard enough of it to-night. The paper is not on honing, and I think it is rather a pity that our discussion has gone on so long on one small operation mentioned in the paper. Taking the paper as read, Mr. Mantell started off with a point regarding the question of rough machining of castings before heat treatment, or heat treating them before any machining at all was done. Heat treatment can be put up to castings for two reasons. One is to minimise the risk of tool damage from hard spots, but also I think, to improve the chances of the casting in service by relieving internal stresses as far as possible. My own experience is that you do not get this relieved to anything like the same extent if you do not rough machine your casting, for heat treatment is often a matter of form, and does very little good unless rough machining does take place first.

With regard to the Brinelling of castings, it has often struck me that a lot of the Brinelling that takes place is often wasteful, because in the first place it may throw out a perfectly good casting, but mainly because I do not believe that Brinell tests on a part of that kind are any criterion as to its machineability. It is a fact that if you take Brinell and Izod tests of the same piece then in some castings you get readings which make the castings appear to be hard, and you get your Izod test piece which makes it appear to be just the reverse.

As to the machineability of a part, if you can arrange to have a small piece to break in an Izod machine, it is going to give you very much better indication.

Pickling is always a bone of contention. One has to pickle castings of course, but I think a great deal more care ought to be given, because I have seen remarkable results of the non-killing of the acid inside the castings. It is wonderful the length of time and the distance into the casting the pickling acid can penetrate, even when one thinks one has killed it most successfully.

With regard to the question of the "push ball" through the cylinder. That is quite an interesting matter, and I believe it can be taken a great deal further than it has been. When you are using that you can vary the results that you get tremendously by your final cut, before putting your ball through. I have never tried it in motor car cylinders, but I have tried it in holes up to 2½ in. diameter, and I have had very beautiful results from it, but to get those results one has to finish with a tool which has a very fine feed, and is almost a sharp pointed tool. If you do that and put through a ball which is only a little larger than the hole itself, you get a beautifully burnished result.

There was a point mentioned about broken taps. There is a little point I might mention, as I have been experimenting with it and that is the use of case-hardened taps. You get the advantage of a very keen good cutting edge, and also you can put your flutes in your taps to such a depth that if a tap breaks all that is all that is necessary is to drill the core, the tap then comes out in four pieces. In my own particular work if one particular thread is broken it costs £20 to scrap the component, so I get over the difficulty in this way.

Mr. Mantell in his paper dealt with all the good things of our lives, but he did not mention any of the difficulties. One thing which has been mentioned particularly in the discussion is the break down of machines, but he does not quite indicate what happens in his flow of work, through rejections and getting out of balance. He runs his times so close into sequence, that I think that his estimated times should have at least a fair percentage added for ordinary difficulties, which we production engineers are largely in existence to cope with. Even in the

matter of hard castings he mentioned his red daubs, but he never tells us whether they come back. They are put on one side for consideration, but he does not tell us when they come into production eventually. I should like to know how he suggests handling them.

Another thing he misses, which he did mention in the preamble to his paper, and that was the question of the centralisation of the bore, equalising fixtures, etc., but he does not deal with that from my point, that is, the preliminary location of the castings, which is a very important matter.

I do feel a little sorry that in his paper he degenerated into the commencement of a description of a progress system, but I am glad he came back to earth again, and went on with the technical side.

I think those are the main remarks, but I do say that whatever we feel about the information that Mr. Mantell did not give us, he has at least given us a very great deal of information, and I feel that the paper, which is very admirably put together, must have taken a very great deal of time to prepare.

REGISTRATION OF ENGINEERS.

Editor's Note.—Since Mr. Hazleton gave his address before the Institution, the Bill for the Registration of Engineers has achieved a certain measure of publicity by receiving a first reading in Parliament. That has focussed the attention of the profession on the subject and the Executive Council of The Society of Technical Engineers, the sponsors of the measure, are now content to hold the matter in abeyance pending a full discussion by a representative body. Thanks to the courtesy of the Secretary of that Council, we are enabled to print the resolution of that body in which they record their decision:—

"THAT in view of the forthcoming informal discussion on Registration at the Institution of Electrical Engineers and also the discussion at the Society of Engineers, steps to present the Engineers Bill to Parliament during the present Session be postponed and that the leading bodies concerned be urged to convene a conference on the whole subject of registration at an early date."

STAINLESS STEEL.

By Dr. Hatfield.

(March 30th, 1927.)

Those who were privileged to listen to the address given by Dr. Hatfield, of the Brown-Firth Laboratories, wondered, at first, wherein lay the "mystery" which has surrounded the treatment of stainless steel.

This frame of mind was engendered by the easy, conversational manner with which Dr. Hatfield handled his subject. Deeper reflection showed that this ease was born of a deep acquaintance with the subject and that only a master could afford to deal with it on such familiar terms.

The lecture was so delivered that it has been found difficult to reproduce it in the formal manner demanded in the "Journal of the Proceedings" of an Institution. Some experiments were carried out and a few slides of Tables were exhibited but in the main the early part of the meeting was devoted by the lecturer in creating an atmosphere conducive to a good discussion.

A distinction was drawn between "stainless" and "rustless" and mention made of the various alloys which are employed to give varying results to meet the many degrees and purposes of "stainlessness."

After a brief address Dr. Hatfield invited questions which were put in such numbers as to pay tribute to the subject in general and the confidence which the meeting had in the lecturer in particular. The points which had, of design, only been touched in the briefest manner were elaborated during the discussion and Members who were not able to be present will gain much by a careful perusal of the information given by Dr. Hatfield in reply to specific problems submitted to him.

Discussion on Dr. Hatfield's Address on Stainless Materials (March 30th, 1927.)

Mr. R. H. Hutchinson: Dr. Hatfield, and Gentlemen,—It is my usual custom to try to give you a lead and open the discussion by making some general remarks. This evening I find it rather difficult because as I have listened to Dr. Hatfield's paper I have had my mind so fully occupied in absorbing the very excellent and interesting information given us. However, I should like to know whether the resistance to corrosion in this steel had any direct connection to the resistance that it offers to cutting, because I

think it is very apparent to us that the old idea of tempering a tool just right for cutting, does not always work with stainless steel Try harder or softer, yet we do not get the difference we have been accustomed to obtain in the past with other steels, and it struck me that possibly this film which protects the steel from the atmosphere may be forming during the period of cutting, possibly forming even more rapidly owing to the heat that is generated and the distortion of the surface left after cutting, and that may have something to do with our difficulties. So far as the various processes of machining are concerned, another remarkable point which strikes one is that although it is a difficult steel to machine (possibly in our ignorance we find it difficult) it is very much easier to machine in some operations than in others. For instance, when one is threading stainless steel it does not offer anything like the same difficulty in the thread milling operation as it does in the dieing operation, or in ordinary screw cutting on a lathe. There is another point I should like to raise. I was not quite clear in the last slide of micro structure which was put on, whether it was actually a non-ferrous metal or whether it was a peculiar form of steel.

Dr. Hatfield: The slide was of the chrome nickel steel. It was of a structure in which no one could tell the difference between a ferrous and a non-ferrous material.

Mr. W. E. I. Gannon (Member): It is with very much pleasure that I have listened to Dr. Hatfield's very interesting lecture, but there are a few points which I should like to query. In a general way when a piece of high carbon steel or chrome carbon steel has been hardened and finished, say a special gauge, unless some artificial aging process is resorted to we find that there is some shrinkage, and it does not retain its standard dimension. Would that degree of shrinkage be greater if this 6 or 8 per cent. nickel was used for that particular kind of gauge. One other thing; I found that in grinding stainless steel in a centreless grinding machine, if the work was not truly cylindrical, but was in any way elliptical, it still retained its elliptical form after grinding, although the grade of the grinding wheel was reduced down to a 60 grit. It was found necessary to have a fine wheel such as a 120 grit in order to obtain finish, and the query is: is it that a certain degree of coarseness must exist in the abrasive wheel to enable it to penetrate the steel. In the case of ordinary carbon or chrome carbon steel, we find no difficulty in using a wheel as fine as 150 grit so one wonders if there is in this particular case a necessity to use a fairly coarse wheel.

I was going to ask the co-efficient of expansion, but Dr. Hatfield has answered that: it is the same as copper. I am rather surprised at that.

Dr. Hatfield: 50 per cent. more than mild steel.

Mr. Gannon: Is the degree of resistance to corrosion somewhat in proportion to the degree of polish on the surface? Also is there any particular Brinell figure at which it is advisable to machine stainless steel?

Dr. Hatfield: To answer a question your President asked, that is: whether there is anything in the resistance to corrosion which bears upon the resistance to cutting. I would answer by saying this: that undoubtedly the characteristics of the material which are responsible for its increased resistance to corrosion are exactly similar to those which resist cutting. The presence of the austenitic structure is the cause of the increased resistance (with reservations which we need not trouble about now) and undoubtedly it is that austenitic condition, which is very considerable at the outset in machining. But there are really two distinct characteristics arising from the same source but are not really associated with one another. That sounds rather paradoxical, but I hope I have made myself clear.

Mr. Hutchinson asked whether the film I spoke about could affect the cutting of the steel. I want you to consider that film as an extremely thin film, of only a few molecules, and therefore from your point of view non-existent. If I were really tied down on that film I should have to admit it is a hypothetic film, but it does not need to be more than a very few molecules.

Mr. Gannon has raised a number of straightforward practical questions and I hope my answers will be satisfactory. In the first place, does a hardened gauge made in carbon chromium steel change its shape? That is so, and the reason is that when you harden carbon steel or steel which has not been loaded with much alloy, it is in a condition in which it does actually change after hardening. You harden the steel and set it on one side, physical changes take place in that steel. Stay-Bright steel I do not recommend for gauges where much wear is likely to be met with. It is soft and cannot be hardened because it will rapidly deteriorate. On the other hand, I do strongly recommend the 14 per cent. chromium stainless steel, because owing to the high percentage of chromium the steel can be well and very satisfactorily hardened, and those shrinkage changes which take place in the carbon steel do not occur. Stainless steel cannot be made so hard as carbon steel and you may take it that in a gauge the hardness figure which can be reasonably expected is 50 Brinell.

The question which you put on grinding is rather more difficult for me to answer. I can tell you that we recommend using a soft wheel, 30 grit with mark Borolon. Does that answer the question?

Mr. Gannon: It would not give quite the degree of finish required on small work.

Dr. Hatfield: I think you are taking me into the intricacies further than I am prepared to go. The best Brinell for machining

depends upon the purpose for which the stainless steel is supplied. That used for connecting rods or turbine blading requires a Brinell figure round about 220.

However, there is a range and I might give you a very wide one from, say, 200 to 235. At any rate the range is of that order, and within that you should have no difficulty in machining stainless steel at, I should think, no more than 50 to 60 per cent. greater overall cost than in the case of mild steel.

In connection with stainless steel, you can take it that a degree of polish is an advantage, but to show you that too much should not be made of it, a ground surface is perfectly satisfactory. In the cutlery trades in Sheffield, they just grind the knife on a grind stone, and the surface thus produced is perfectly satisfactory.

With rustless steel, nothing over a decent grinding finish is required. There is this to be said, that in grinding one can overheat the surface and scorch the metal, and so obtain a film hardly discernible to the eye. In the ordinary way one might think it just slightly yellow, or not notice it at all. If corroding media comes in contact with it, it would probably remove that effect in patches, and then the reverse effect of staining becomes obvious through the scorch effect being prominent. That is quite an important point in some applications of the steel. As regards Staybright, anything from a tolerably rough machined surface up to a commercially ground finish is quite all right.

Might I suggest that I am cross-examined on such questions as welding and that sort of thing. We have quite a lot of experience, welding, soldering and, of course, machining. Welding may be done either with the oxy-acetylene flame or by electric methods. It can be done on the smith's hearth, but the time required to attain a suitable temperature allows scale to form and then one has the undesirable feature of a scale between the surfaces to be welded. In oxy-acetylene one rapidly obtains a temperature, and the same applies to electric welding. Electric welding presents no difficulty once one has mastered the technique. To the oxy-acetylene process I apply the same remark, but I would point out that oxy-acetylene carburises very hot steel rapidly and unless the flame is correct carbon comes into the steel from the acetylene. I cannot show the experiment to-night, but I can describe it to you. In the acetylene flame can be observed what is called a feather. That little feather should be just discernible, for then there is a balance of oxygen and acetylene and one can weld up without any difficulty. If one carbonises then the hardness of the weld is very much increased. The increase in hardness and general change in the physical properties may result in a crack in the weld.

The other point to watch in welding is, of course, that the parts themselves do not move by stresses in such a way as to

break the weld. That is the case of adjusting the work in the welding operation. Electric welding is quite as easy as the other, and if any of you are interested and have difficulties I shall be very glad to give an actual demonstration. It is sometimes said to me, particularly of the chromium nickel steel, that this material is often difficult to machine, and cannot be rivetted. I am in the advantageous position of being able to point to some application here or there which answers all the questions raised. I can point to huge structures; structures which are portable; to ordinary blast furnace structures where all the sheets are rivetted. I can point to similar structures in Staybryte in which tons of rivets have been used successfully, where tens of thousands of holes have been drilled under commercial conditions. It is only a case of appreciating the characteristics and one gets away with it easily. Turning sometimes presents difficulties, and in that instance the tool angles should be generally more acute than for cutting ordinary steel. The front rake should be 15 to 19 deg., front clearance 6 to 10 deg., side rake 4 to 6 de. All that information is available to those interested, and I shall be glad to let them have it without boring you with a lot of statistics in my attempt to elucidate questions from you for the discussion this evening.

MR. OAKLEY: Would the author shed some light on the question of the state of stainless steel as delivered at the present time to the average user, is in correct physical state for machining or not? My experience of some stainless steel is that it has not been subjected to an appropriate heat treatment, and the majority of firms are not in the position to heat treat it themselves. Some firms try to heat treat it after receipt, but I think without success. In my experience, the general nature of steel is that it tears considerably and the feed has to be reduced something like 50 percent below ordinary nickel steel.

DR. HATFIELD: Can you compare it with mild steel?

MR. OAKLEY: No! but comparing it with nickel steel, we have found the cost in turning, for instance, was much higher.

DR. HATFIELD: We have proper equipment for producing steel in the condition that we think is the best for machining. "To err is human, to forgive divine." We do our best and I suggest that you see that the steel shall be supplied in the best machining condition. You ask what is the best machining condition for this particular steel? If you are talking of the turbine building material, I have given a range of Brinell which is as close as possible, and should cover machining properties, and it is for you to see that the steel is within that range. I am sorry to say that all new materials are subject to the same complaint. If new materials are put on the market, the manufacturers are in a hurry to get them adopted, and the time was, but is not now, when the industrial side of the manufacture was not as completely understood as it

ought to have been. To-day, as the result of experience, we know what the conditions should be to machine as satisfactorily as one can hope to machine them, and we always aim at those conditions in sending out the materials when we know it has to be machined.

The treatment we submit it to and which I can recommend is this: It should be hardened in oil to a temperature round about 950 deg. C., and then tempered at a temperature of about 780 deg., C. After that treatment there will be no unreasonable difficulties in machining. If difficulties are still experienced, do not give suppliers the benefit of the doubt, but test out the material by the Brinell method and also ask them to investigate. In all works we have to depend on workpeople. We give our instructions, but it may well be something gets out which ought not to be. If a consignment of stainless steel does not machine very well, investigate and let it be determined whether the steel is not in the condition which it ought to be, or whether there is some little modification of technique which we can explain to make machining easier. To answer your question directly, I would say that the steel is supplied in the condition in which it should be machined. That is when it is to be worked from the bar, not when drop forgings are made from it.

A VISITOR: I was rather interested in Dr. Hatfield's references to welding and stainless steels, and I shall be glad if he will tell us a little more about the electrical methods of welding. I have seen some very good samples of Staybryte steels welded by the resistance process, both spot- and machine-welding, and so far as I know the welds were quite satisfactory as far as their resistance qualities are concerned. I think Dr. Hatfield had in mind the electical process, and I shall be glad to know what type of electrode was used, and presume that the core was similar to the material; also was there any after treatment?

DR. HATFIELD: No after treatment is necessary. That is a general statement and I had better make a reservation. The steel, owing to its composition, freezes in position and is so ductile that I can take two pieces of sheet and weld them and let them cool down naturally without any further treatment, then open them out again without the welding being destroyed. That discloses a capacity for specific formation in a welding material that is greater than in the case of any ordinary steel, and therefore is very valuable in its application in many instances where it would be undesirable to heat treat. The only instance where heat treatment is necessary after welding is when making receptacles for dealing with certain organic acids which are just touch and go, the steels will resist in those cases where by heating up again or cooling in the air the steel becomes completely resistant to acids.

VISITOR: It would be interesting to know whether the flux is

used to compensate for any variation in the core, or is it merely a protective coating

Dr. Hatfield: A coating, or flux is not necessary but the flux may be regarded as an additional safeguard in cleaning the surface.

Visitor: I should like to ask Dr. Hatfield one point which has not been touched on, that is, the annealing of pressings. Some time ago we used a number of brass pressings, 2in. diameter, 5 or 6ins. deep, and for special purposes we wanted some in stainless steel, and a firm in the Midlands making the pressings (we wanted about 100) delivered 50, and then asked to be let off making the rest. The trouble was in the annealing. According to them, they had to get the temperature up to about 1,200 deg., C. in order to anneal the steel.

Dr. Hatfield: Annealing for press work is best achieved by heating to any temperature over 1,000 deg., C. I prefer it over a thousand, but economically and industrially there is a great difference between 1,000 and 1,100, therefore I am not going to be too insistent so long as it is taken over a thousand. Only for a couple of minutes, it is quite long enough, then cool it in air and it will be sufficiently soft for forming.

Mr Gerard Smith: I have one particular application which brings out a point which has not yet been mentioned. We want the material in 16 gauge strip form for stamping a hammer whose work is somewhat similar to that of a typewriter type-holder, only in this case the hammer hits on the back of the stationary type instead of carrying the type on its own head. It works at several strokes a minute and we want ti to work for 20 years. We also want on certain portions of it a glass hard surface, firstly to prevent spoiling the hammer surface and secondly against wear on the bearing surface. With the ordinary steels we have troubles with oxidisation, simple rusting, drying up, and other usual causes. The parts do not get pure nitric acid or anything of that nature, but when the part has been machined to size and plated it has several thous. on either side; the plating goes very soon, and therefore there is every reason for using stainless steel if it will stand up to crystallisation, especially if one can get a glass hard surface to withstand repeated shock.

Dr. Hatfield: The rupture by crystallisation which you mention is perhaps the most important feature, and really one does not get crystallisation. What actually occurs is failure from fatigue (we are talking now of stainless steel). The 40 per cent. chromium stainless steel would admirably suit the purpose you have in mind. It has a fatigue value of about 22 tons per square in. and is in the same order as the best alloy steels, say 50 ton nickel steel in its 50 ton condition. There is a sufficient capacity for plastic deformation to take care of the effect of the elastic range.

I speak with great diffidence on this subject, because the master of the subject is here, and I hope he will say a few words later. As regards the wearing surface, one can obtain a film of hardness by the flame effect. You know there is a way of hardening gear surfaces by an oxy-acetylene local heating, followed by rapid cooling, so I should imagine that stainless steel will fill the bill. On the other hand, I hold such an opinion on the fatigue question as to give a dogmatic reply. It may well be (and I fear what I have to say is rather strange) that in that particular application is required very much more ductility in the material to prevent rupture can be given in either stainless steel of a tensile value of 50 tons. It is sometimes found in these conditions that fatigue is overcome by lowering the fatigue range, and by using the material with a much greater capacity for plastic deformation. This is probably illustrated in a case extremely similar, that of tramway axles.

It is known that the tramways of various corporations differ very much, and I know corporations where for some time past complaints have been made about broken axles, which have probably been made in 35 carbon steel. The conditions are examined, and a higher tensile steel with a higher elastic range, say nickel chromium, is recommended in one case where in one year 18 tram-car axles were broken, high tensile nickel chromium steel was used and from that day to this, about four years, they have not had another broken axle.

The are other cases where putting in the higher tensile steel simply increases the number of breakages, and the solution was found in putting in an axle of much greater ductility, so that without more knowledge of the precise case mentioned I cannot give a definite opinion.

Mr. Gannon: I should like to take advantage of Dr. Hatfield once more. Where two surfaces are continually working against the other, would stainless steel have a better resistance to wear than ordinary carbon steel?

Dr. Hatfield: Do you mean two surfaces of stainless steel?

Mr. Gannon: Not necessarily the same. For instance, if a spindle continually rotating in bronze is made from this 14 per cent. chromium steel, would that spindle be better than one made from direct carbon steel?

Dr. Hatfield: The answer is that such spindles are giving every satisfaction. That is the practical answer. If one comes down to the intrinsic merits of the case one can observe that probably the user or the manufacturer of the spindle has not perhaps used the best material for the comparison to be made. It is known that for resistance to wear a carbon steel round about 0.7 gives extremely good value, hardened and tempered stainless steel of 50 tons tensile also gives good value, but obviously one

would not use stainless steel where a carbon steel is good enough. If one wishes to utilise the resisting properties of stainless steel we can provide a material that will be sufficiently wear resisting to be applicable to the job. However, I do not think that the stainless steel will give quite as good a resistance to wear as straight carbon steel.

Mr. Gannon: The reason I raised the question is because, with spindles working under certain conditions, it is very important that machine stoppage for the purpose of adjustment is prevented, therefore if the length of run can be extended by using any particular material, it would be of great advantage.

I made this test some little time back. An 0.8 carbon steel roller was ground to a very fine finish. This roller was caused to rotate by its own weight on top of a cast iron disc 9 in. diameter, its surface being ground perfectly true, and running under very exact conditions. The roller was allowed to rotate almost on top of this disc, with just a small barrier to prevent it rolling from one side, and keep it in a parallel position. It was allowed to rotate for 30 hours, and was found that it had worn away to the extent of 0.0018 of an inch. Another test was made with a similar size cylinder finished under the same conditions but made from an 0.6 chromium alloy steel, and I believe of the same carbon content. In the same period of running time the only amount of wear which took place was 0.0003 in. That seems to show that the presence of chromium very much added to the resistance to wear, therefore I thought that the increased amount of chromium in stainless steel, not necessarily 14 per cent., might also add to the resistance to wear.

Dr. Hatfield: The surfaces were rotating on one another giving metallic contact. As regards pure wear of that kind, where corrosion does not matter, I would recommend stainless steel. I am not at all convinced that the intrinsic merits of the two steels were brought out in your tests. A comparison of that kind is very difficult to obtain, owing to the mathematical exactness required in repeating the conditions.

Mr. Gannon: It was repeated, and the results were usually similar. Almost mathematical measurements were taken by measuring machines, and the experiments were conducted in such a manner as to exclude any dust in the atmosphere.

Visitor: Another point. What degree of scratching or surface marking would impair the rust resisting qualities of stainless steel? With regard to the 14 chromium Staybryte steel, is the rustless under all conditions?

Dr. Hatfield: The distinction is merely in rustless and stainless Stainless is a most exacting requirement as will be appreciated. There are millions of stainless knives in service, which have been very badly used, and they are simply covered

with thousands of scratches, yet they are still stainless. As regards rustlessness, anything better than a good machine surface will produce satisfactory results. May I just explain? You will appreciate after my rather rude remarks about your operation of machining that material is very soon damaged, so that if a rough turned surface is examined under the microscope a large number of crevices and badly formed portions may be observed. The degree of surface which is required is that necessary to remove the very badly damaged surface caused by rough machining.

VISITOR: Can any idea be given as to the ease of machining Staybryte steel? Has it got better properties than the ordinary stainless steel?

DR. HATFIELD: It is easy to machine, but not as easy as mild steel. It costs twice as much to machine as mild steel. However, it is a very good commercial proposition to machine it. The main advice I can give is that the tool must not dig into the material.

VISITOR: With regard to 14 per cent. chromium stainless steel of 200 Brinell, what approximately would be the ultimate yield?

DR. HATFIELD: 200 to 235 covers the range of maximum stress of about 43 tons up to about 52. The Brinell factor in the case of alloy steels in general, if multiplied by 0.23 will give the maximum stress. With all mild steels the Brinell number should be multipied by 0.25 to obtain the maximum stress.

MR. MANTELL: As an "apostle of brutality," (within certain limits), I was amused by Dr. Hatfield's reference to that characteristic of production engineers. To save us from ourselves, may we have some information on the best speeds and feeds to use when turning and screw cutting. Some friends of mine who are here this evening were up against the screw cutting of stainless steel, and I had the pleasure of sharing in their experiments. Complete results have not yet been obtained and Dr. Hatfield's comments would be appreciated.

DR. HATFIELD: For finishing at high speed consistent with accuracy say 40 to 100 feet. You see without knowing something about the geometry of the tool, you cannot expect me to give you very much information. If you start at 70 feet as a basis, then you rapidly get what you want.

I have a few notes here about cutting speeds that we have found effective. For roughing, if the material has a tensile strength of 45 to 50 tons, about 55 feet per minute is found satisfactory. If the tensile strength goes up to 55 to 60 tons, the speed drops down to about 42 feet per minute. For finishing, according to the tensile strength, the speed will be down to 80 feet per minute. These are figures from our own shop.

MR. MANTELL: Can you quote figures on automatic production where there is no roughing and finishing operation, but the work is completed in one cut?

DR. HATFIELD: No, I think my first answer to you is the correct one. I feel sure that by slight adjustment of the geometry, front clearance and side clearance, you will overcome difficulties, but each case must be considered on its merits.

VISITOR: Mr. Mantell has referred to some of our difficulties in machining of stainless steel, particularly in threading. The plain turning and point tool screwing did not present any real difficulty. We have found that in screwing with a die it is almost impossible unless using a self-opening die head, and that preferably with the tangential chaser. For a cutting lubricant we use Frappol. I do not know who the maker is, but the results obtained are quite 30 per cent. better than with the ordinary cutting lubricant.

MR. HUTCHINSON: There are one or two questions I want to ask. Is it possible to form a hardened zone on the surface such as might set up minute cracks and fractures on highly stressed parts when finishing stainless steel? I have in my mind the kind of zones which are frequently formed on alloy steels in grinding. Is it possible to get these zones from lathe tools as well as grinding?

DR. HATFIELD: Locally tool hardened, but I do not think that can cause failure in the manner that you suggest.

MR. HUTCHINSON: When we grind the surface we get the minutest re-hardened zones, sometimes only a few thousandths of an inch in length. Much dirt gets into the zones, which will lead ultimately to the failure of quite expensive parts. There was a point raised about spindles. We know there are very many cases where stainless spindles are very useful. It will be interesting to know which is the best, white metal, gun metal, or other material to use with a stainless shaft.

DR. HATFIELD: I prefer white metal.

MR. HUTCHINSON: Now as regards the matter of the film. We all realise that the most difficult machining operations to perform on stainless steel are those of tapping, reaming and broaching. Now these are all operations where it strikes me that this film which forms might have something to do with our difficulties, because the main difficulty we have is the picking up of the work on the tool, particularly in tapping.

With regard to broaching, I am not at all sure that the Brinells mentioned, even if you go up to 310, overcome the difficulties that we have in mind. Metal always seems to drag and tear. As far as the mention of Frappol is concerned, I have had some experience in using Frappol in precision machining, but there are various other similar compounds. Another very good one is Toppoil, but the best coolant of any for light cutting work on stainless steel is undoubtedly Lagoil if a good finish is required. There is just one other thing about welding. Dr. Hatfield mentioned that it was impossible to harden Staybryte, yet when Stay-

bryte is welded one of the difficulties to face is that adjacent to the weld the metal gets very brittle. Is not that a state of hardness?

DR. HATFIELD: Unfortunately, but not a state of Staybryte. I agree with your suggestion that if Staybryte is carburised it is made hard, but there are introduced characteristics which one would rather not have there.

MR. HUTCHINSON: I must add that we are all very grateful to Dr. Hatfield for giving us an extremely instructive and interesting paper. Very often one sits and listens to a paper being read, and although I think one can always learn something, there seems to be a great deal of matter put before one, about which one knows a great deal. This evening I feel that the order of things has been reversed. Dr. Hatfield has come along to us and given us a lecture, not in the ordinary way, and it shows what a wonderful master of the subject he must be.

DR. HATFIELD: I thank you very much for the kind reception of my paper. In developments of this kind you, and those like you, are doing even more than we are in the laboratories, in the development of these new materials. It is only by you attempting and we trying to help you that we can achieve progress. May I say this, that if any of you are interested in the technology of the subject, I shall be pleased to let you have any information that would be of use to you.

LIGHT ALLOYS.

By Dr. Leslie Aitchison, D.Met., B.Sc., F.I.C., M.I.A.E.

Being a Paper presented before the Institution at the
S.M.M.T. COUNCIL ROOM, 83, PALL MALL, S.W.1.
April 20th, 1927.

In lecturing on the subject of light alloys, the first thing necessary is to give an answer to the question, "What is a light alloy?" because many different definitions can be given as to what constitutes a light alloy, particularly by engineers. In the first place I do not think that it would be entirely right to say that a light alloy is simply a material having a low specific gravity, because such a material may prove very heavy in actual fact. For instance, if one contemplates the manufacture of a part requiring very great strength, and one uses soft aluminium, the result will not be a

particularly light article. In fact, if one uses aluminium with a 5 ton maximum stress, the eventual article will be six times heavier than if 100 ton steel is used. This is, of course, a question of point of view, and fortunately for those present, I do not intend to pursue it very far. I might involve myself in a very considerable discussion, and find myself covering the whole range of known metals. Therefore, I am going to say that light alloys are those materials which have intrinsically a low specific gravity, and for the purpose of this evening's talk I am going to consider particularly those materials which have a specific gravity which is not greater than 3.

Even accepting this limiting definition, the field to be covered is a tolerably large one. One can discuss alloys which are based upon three quite definite and distinct basic metals, namely, aluminium, magnesium, and finally beryllium. I do not propose to talk about beryllium, firstly because not very much is known about it, and secondly because we, as practical people, are not likely to be concerned with beryllium for some time to come, in consequence of its high price. As far as investigation has gone, beryllium has proved to be a little disappointing. It possesses, of course, certain interesting and important physical properties,—amongst others, a high melting point which makes it rather attractive to those who have any interest in the pistons of internal combustion engines. Actually the melting point is of the order of 1180 deg. C., i.e., nearly twice as high as aluminium or magnesium. Beryllium also has a high maximum strength and a high Brinell hardness, but as far as experimental work has been carried out up-to-date, the material has not been prepared so as to exhibit a high degree of toughness or ductility. It is a rather brittle but strong material. Unfortunately also, the alloys which have been formed with beryllium and aluminium partake of the brittleness of the beryllium. This interesting metal, of course, is merely in the experimental stage at present, and, as the price of the metal indicates, not a very large amount of work has been successfully carried out on the extraction of beryllium. So much then for a material we do not propose to discuss.

With regard to magnesium, I think we may make some reference to this metal if there is time, at the end of the evening. Magnesium has properties which are not so attractive as beryllium. It is not a hard metal, being on the contrary rather soft, and most of the alloys of magnesium tend to be proportionately soft. They are particularly soft when measured by the Brinell hardness. The main difficulties with regard to magnesium, however, and I think the only things which really prevents a much more extensive application of this metal in engineering, are, firstly, the difficulty of preventing corrosion, and secondly, the extreme difficulty of casting magnesium or its alloys in a satisfactorily sound

form. Anyone who has had experience of this material will agree that the casting of the metal is extraordinarily difficult, and that when this particular difficulty is overcome, a much more extensive use of the metal is likely to follow.

Finally, there is aluminium, and in talking of light alloys, this metal and its alloys are bound to bulk far greater than any other material. In the alloys of aluminium and aluminium itself, one covers an enormous range of mechanical properties, extending on the one side from a material which is comparable in its properties with soft copper, to a material at the other end of the scale which may be compared in its properties with mild steel. This is a considerable range, yet all these properties can be found in alloys within measurable distance of pure aluminium, and moreover, without departing very considerably from the low specific gravity which is a characteristic of this particular metal. One should realise that the specific gravity of aluminium is 2.7, that of steel being 7.7, and that of brass 8.4, and of copper 8.8. Thus in aluminium one has a material which is approximately one-third of the weight, volume per volume, of steel, and less than one-third of the weight of brass or copper.

Aluminium and its alloys will, therefore, be considered first, and I would like to try and make some sort of classification which will be generally useful. Any such classification of these alloys is bound to be rather arbitrary. One could, of course, classify the aluminium alloys on the basis of their mechanical properties, say the strength at ordinary temperatures. On the other hand, one could classify the alloys on their specific gravity, taking those ranging from 2.7 to 2.8, 2.8 to 2.9 etc.

The method I propose to adopt is rather different from these, and is based really upon the essential characteristics of the different types of alloys. I propose, therefore, to divide aluminium and its alloys into five groups. The first group is a very small one, consisting entirely of pure aluminium. In the second group we will discuss those alloys of aluminium which are useful only in a cast condition, i.e., those materials which are only used as cast. In the third group I think we might consider the alloys of aluminium which are cast, but which before casting are modified, that is to say, subject to a certain treatment or process while in the molten or liquid condition. In the fourth group we can consder those alloys which can be cast but which are susceptible to modification after casting. Amongst these are included metals which may usefully be submitted to some treatment which will improve their properties when in the solid state. Finally, we may deal with those alloys which can usefully be worked and can be used in the worked condition, the working being done either in the hot or the cold state. The five groups, therefore, are roughly pure aluminium,

simple casting alloys, modified casting alloys, cast alloys which can be subsequently heat treated, and alloys which can be wrought or forged and heat treated afterwards.

The properties of pure aluminium need not concern us very much, but it is just as well to review them, as they form the basis upon which all comparisons must be made. The specific gravity of the metal as already mentioned, is 2.7; the maximum stress, which is the usual criterion of the strength of the material, varies from 4.5 to 11 tons, according to the amount of cold work which has been applied. In the soft or annealed condition it is 4.5 tons per square inch. The elongation per cent. of an ordinary piece of aluminium which has been annealed is 40 to 45, which again is rather similar to that of soft copper. Aluminium is a particularly soft, ductile and weak material.

In the second group, which includes those materials which can be employed as cast, an enormous number of alloys may be mentioned. I do not think that I am over-stating the case when I say that aluminium has been alloyed with every other known metallic element at some time or another. The resulting experience has been definitely to show that it is quite unnecessary and unremunerative to use any rare metallic element in these simple alloys. Quite as satisfactory results can be obtained by the use of common metals such as zinc or copper. As far as alloys with the metallic elements are concerned, when used in cast condition, zinc and copper produce results which are very satisfactory, and which cannot in general be surpassed. We might also say, therefore, that alloys of aluminium with these metals have eliminated all competitors in this field.

The first slide shows the mechanical properties obtained from a chill cast test piece by the addition of certain percentages of copper and zinc to aluminium. It will be seen that the highest value is obtained when 15 per cent. of zinc and 2½ per cent. of copper have been added to the aluminium. The test indicated is a very satisfactory one giving 15 tons per square inch maximum strength with an elongation of 16 per cent. The specific gravity of the material, however, has risen from 2.7 up to a value of practically 3.0.

In the next slide we have a series of mechanical properties which are perhaps easier to follow than those on the last slide. The values shown indicate the result of adding progressively larger amounts of zinc to the aluminium. Again the test pieces have been cast and dealt with under favourable circumstances, and the cumulative effect of the addition of larger proportions of zinc is, very obviously, enormous. It is quite evident that as zinc is added, the first effect is to increase the maximum stress of the material. The second effect is to decrease the elongation per cent., whilst the third obvious result is that the

specific gravity of the material is considerably raised. It will be seen that the best result is 13½ tons maximum stress, which represents an increase over plain aluminium of 260 per cent. The specific gravity of the strongest material has, however, risen up to rather more than 3.

In the next slide a similar series of test figures obtained by the addition of copper is shown. Here again the general result is somewhat similar to that produced by zinc, although possibly not quite so marked. The maximum stress eventually rises to a figure of rather more than 10 tons, whilst the elongation has come down nearly to vanishing point, and the specific gravity has risen to 2.9. Incidentally, it is essential to consider the matter of specific gravity in the right light.

An actual increase of specific gravity of 0.4 does not perhaps sound very much, and if one is working in brass or some heavy material, such a change would hardly be appreciable. An increase of 0.4 specific gravity in the alloys of aluminium is, however, an increase of nearly 15 per cent., and of course the addition of 15 per cent. to the weight of a structure represents a very considerable amount. We can imagine the the effect of suddenly increasing the specific gravity of light alloys in an airship by 10 or 15 per cent. The structural weight is increased by a similar amount, and therefore the useful lift of the airship might be reduced by anything from 40 to 50 per cent. There is, therefore, a great deal of point in keeping down the specific gravities even of light alloys, and in aiming to have the specific gravity of the resulting alloy nearly the same as the parent aluminium which is the basis of the alloy.

From the three series of test figures which have been shown above, it is possible to form some general conclusion as to the mechanical properties of the main casting alloys of aluminium. In all instances one is limited in the increase of maximum stress by the very serious decrease in ductility which follows. It would be possible to go on increasing the maximum stress of aluminium zinc alloys even beyond 15 tons per square inch by adding more copper or magnesium, etc., but such an addition would certainly decrease the elongation and, of course, increase the specific gravity still more. Another difficulty also arises, in that the materials become almost impossible to cast properly.

The cast alloys of aluminium may be summed up by saying that from 10 to 11 tons maximum stress with an elongation of approximately 4 per cent. can be obtained. The specific gravity of such a metal will be round about 2.95, whilst Young's modulus is about 4,000 tons per square inch. It will be seen that the properties of the cast aluminium alloys are very similar to those of cast iron. There is very little to choose between these metals, and it is safe to say that a job which can be done in cast iron can be done equally well in cast aluminium alloys, providing it is

not a large one. This reservation is due to the fact that the difficulties of casting large masses are much greater in aluminium than in cast iron.

In the third group of the adopted classification, we can consider briefly the alloys which can be modified even when in the molten condition. This particular group is not very extensive at the moment, but there are indications that more alloys will in the future have to be included therein.

The most conspicuous examples of this group are the alloys of aluminium and silicon. These have the remarkable property that when cast without modifying they are brittle, but if cast after suitable modification, they are comparatively tough and ductile. It is not known what is the actual machinery of the modification process, but one can profitably consider parallel results. Taking, for instance, a 10 per cent. silicon aluminium alloy in the non-modified casting, the maximum stress is approximately 10.5 tons. After modification the figure will be in the region of 12 tons, whilst the elongation which in the non-modified casting was about 3 per cent will be increased by modification to approximately 9 per cent.

The processes underlying the modification of these alloys are of considerable interest to metallurgists. They are not so interesting to engineers except as to the results obtained, and the modification process may be summed up for our purpose by stating that it really consists in preventing the alloy from separating out into comparatively coarse crystals during solidification. The size of the crystals formed when a metal solidifies, exerts a very marked difference in the properties. A coarsely crystalline structure is very much less ductile than one with a fine grain, and the aim of the modification process is to produce a fine structure closely and intimately knit together.

The process can be carried out in more than one way. It can be brought about by chemical means, i.e., by the addition of a catalytic re-agent which produces the desired change in the metal. A very similar result can be produced by allowing the material to cool quite rapidly, i.e., by casting it quickly and chilling it severely so that it passes speedily from the liquid to the solid state. Casting in powerful chills is a definite means of bringing about this modification, and since this is one way of inducing the change, it is impossible to expect modification in large masses. This is precisely what happens. If the alloy is cast in large lumps, the interior of the casting is almost invariably in the non-modified state. It may be taken that if the section of the casting is over 3in. in thickness, it will almost invariably have a coarse structure in its core, although the outside has been successfully modified by the more rapid cooling which has taken place on the exterior.

The next group of metals consists of those alloys which can be successfully modified after they have become solid. This opens up quite a different branch of light alloys from anything we have so far considered. The modification in the solid state must be carried out by heat treatment processes, and if the alloys in question are susceptible to heat treatment they must in certain respects have points of similarity with steel. It is well known that the hardness of steel can be increased by heating the material up to a certain temperature, then cooling it rapidly, i.e., quenching it out. In this particular process there are two essential features. The first is that the steel must be heated up to a certain minimum temperature before quenching, i.e., the steel has a certain critical temperature above which it must be heated prior to hardening. The second essential is rapid cooling, which is carried out with the express purpose of preserving the structure of the material during cooling.

Now the light alloys are very similar to steel in those two essential features, and the heat treatment follows closely upon the same lines as that of steel though there is one point of difference which will be emphasised shortly. With the class of light alloys about which we are now speaking, it is necessary for them to be heated above a certain specific temperature. All the alloys that I am aware of which respond to heat treatment must be heated above a temperature of 450 deg.C., if the treatment is to be successful. From this temperature they must be cooled rapidly. The degree of rapidity of cooling with light alloys is not, however, so great as in the case of steel. Ordinary carbon steel particularly must be quenched rapidly in order to harden it. Nickel chromium steel can be hardened quite slowly. High speed steels can be hardened in an air blast, or in oil for large masses. In the case of light alloys, air cooling is sufficient for very small masses, whilst medium sized parts can be cooled quite efficiently in oil. Large components, however, must be cooled out in water. The two essential features in the heat treatment of light alloys, therefore, are heating to upwards of 450 degrees C., and rapid cooling from this temperature.

Amongst the wide range of light alloys only a comparatively small number will respond satisfactorily to any heat treatment process. The alloys that are treated most satisfactorily are those containing magnesium, silicon and copper. It is possible, however- to obtain satisfactory heat treatment results on a distinctly smaller scale from alloys which contain only copper. The light alloys which are most suitable for heat treatment, however, contain several other elements, including the above.

The essential point of difference mentioned above between the heat treatment of light alloys and that of steel is very marked and must be appreciated thoroughly. This relates to the ageing

or tempering process. If a piece of steel is heated up to the correct temperature and quenched out rapidly, and tested either in tension or by the Brinell method, the material will be found to be as hard immediately after quenching as it will be in say a week or month after quenching. There will be no appreciable difference between the degree of hardness when tested 10 minutes after quenching or 10 years afterwards. Now this is not true with aluminium alloys. When these are quenched from the correct temperature they are quite soft, in fact, as soft as if they had been annealed. If, however, the alloys, which when quenched are quite soft, are subsequently allowed to stand for a certain period of time, it is found that they become progressively harder. After the lapse of a certain number of days the materials have hardened up to a value very much greater than the previous figure obtained immediately after quenching. For example, with an aluminium alloy, the maximum stress may be 15.5 or 16 tons per square inch immediately after quenching, whereas after ageing for a week the maximum stress will have risen to 26 or 27 tons per square inch.

It is possible to give a parallel case in the treatment of steel which will perhaps be more clearly understood. Many of the members are no doubt well acquainted with manganese steel, or 25 per cent. nickel steels. Manganese steel is the famous Hadfield steel which is used for tramway points, whilst 25 per cent. nickel steel, although not used very extensively nowadays has the same property that when quenched it is quite soft and non-magnetic. Both these steels are typical engineering steels, and when quenched they are quite soft and will stay soft unless they are mechanically worked in some way. For example, if tramway points are put down soft, they become quite hard after a certain amount of wear. In the language of metallurgists, the materials when soft are in the austenitic condition, and they pass into the martensitic condition by mechanical working or the application of heat.

The aluminium alloys under discussion are very similar. When quenched they are in the austenitic or the soft state, and they automatically pass into the martensitic state simply by the passage of time. The reason for this is that the atmospheric temperature is the tempering temperature for these alloys. That is to say, ordinary temperatures applied to aluminium alloys have an equivalent effect to temperatures of 450 deg. C. or over applied to steel. This, of course, is quite logical when the other properties of the alloys are borne in mind, and it may be stated that with some exceptions, to which reference will be made, aluminium alloys temper themselves at room temperatures if they are suitably composed.

The next slide shows the effects produced upon a certain type of aluminium alloy containing copper, magnesium, and silicon, as well as nickel. It will be seen that the mechanical properties are modified by carrying out the treatment described above.

The tests were taken at the National Physical Laboratory, and are perhaps not too typical of everyday practice. It will be seen that in the ordinary cast condition, the material has a maximum stress of about 14 tons per square inch, and an elongation of about 3 per cent. After it has been heated for a considerable period to 520 deg. C., and then quenched out in water and allowed to stand for six days, the maximum stress has risen to 23.5 tons per square inch, whilst the elongation is 14 per cent. This represents a very considerable increase, and the test figures are remarkable for material in the cast condition. An important feature is that the temperature of 520 deg. C. must be maintained for a relatively long time, this being mainly due to the fact that the casting under treatment has a naturally coarse crystalline structure. If that structure were broken up or refined by any suitable process, the time for heating at the quenching temperature could be reduced to a matter of minutes instead of hours, so that the same effects could be obtained much more rapidly. The most satisfactory way of achieving this result is to apply mechanical work to the material.

This naturally leads to group five of the light alloys, i.e., those which can be satisfactorily worked. Actually there are only two (and in reality these are essentially the same) which need to be considered, i.e., Duralumin and "Y" alloy. These are the typical alloys in this group, and on account of its pre-eminent importance in modern applications, reference will be made mainly to Duralumin. This metal is one of those alloys which can satisfactorily be heat treated, i.e., modified when in the solid state. It consists of about 94 per cent. aluminium, 4 per cent. copper, 0.5 per cent. manganese, 0.5 per cent. magnesium and 0.5 per cent. silicon. At the outset it may be stated that this alloy has mechanical properties which render it quite reasonably comparable with mild steel. Suitably treated it has a maximum stress of 26 tons per square inch, and an elongation of over 20 per cent., whilst the specific gravity is very little greater than that of aluminium, being actually about 2.8. Moreover, the alloy responds readily to heat treatment, the rapidity of its response being mainly a result of the working of the alloy. Duralumin, however, is always worked, being produced either forged or drop forged, extruded or rolled in sheet, rolled or drawn in wire or sections, etc. Whatever the process, in every case the material is submitted to mechanical work, either hot or cold, after casting, and before the heat treatment process is carried out, the result of the working being to produce a finely divided structure. The heat treatment of this metal may be followed out in comparative detail since it fully illustrates the principles referred to above.

The next slide shows a series of tensible tests taken on Duralumin which has been heated up to various temperatures and then cooled quite slowly. It will be seen that the

material, which is originally in the soft state remains quite soft and is practically unaffected by re-heating to any of the temperatures chosen up to approximately 500 deg. C. It is impossible to go very much above this temperature because the material in this group of light alloys containing copper begins to melt at 545 deg. C. These tests have been taken on samples which have been heated up to the temperatures shown, afterwards being cooled quite slowly and then allowed to age.

On slide 6 are shown the results obtained by taking a similar series of test samples up to the same chosen temperatures and cooling rapidly. The test pieces were all quenched from the temperatures indicated, but the tests were made immediately, i.e., within half an hour of quenching. It will be observed that there is no very marked change, but at the upper end of the scale the material is beginning to harden, though there is not a very big increase in the maximum stress of the material.

The next slide gives the results from similar series of specimens which have been quenched out from a variety of temperatures and then allowed to stand for a period of five days prior to testing. It will be seen now that the material which has been taken up to a temperature of 500 deg. C., quenched out and allowed to age, shows an increase in its strength of 10 tons per square inch over the the original figure. A strength of 16 tons was a more or less general figure before the commencement of treatment.

The above tests emphasise one or two important points. Generally speaking, they indicate that the higher the temperature to which the material is heated before quenching, the higher is the ultimate maximum stress. It is reasonable, therefore, to ask, "Why not go higher than 500 deg. C.?" It is true that the strength would be slightly higher if one went over 500 deg. C. but in actual practice it would be difficult, if not commercially impossible, to use a temperature of, say, 525 deg. C., because the material commences to melt at 545 deg. C. Temperatures above 500 deg. C. are, therefore, so near the melting point that the material becomes soft, and it is difficult, if not impossible on a commercial scale, to retain the shape of the components. Further, there is always the tendency that temperatures higher than 500 deg. C. will develop local defects which are rather similar to those produced when steel is overheated, i.e., local burning. If attempts are made to work at 525 deg. C. this local burning is almost certain to occur sooner or later. As the most satisfactory working compromise, the manufacturers of Duralumin strongly advise a temperature range within plus or minus 5 deg. of 485 deg. C. This will give all the necessary mechanical results required.

The second important point arising from the above test figures is in connection with the correct softening temperature for the alloy.

From the figures it will be seen that it lies somewhere between 350 deg and 400 deg. C. If the metal is taken up to 400 deg. and not cooled very slowly, it will be hardened in some measure. At 350 deg. C. the material is not quite fully softened, and it should be heated actually to a temperature of approximately 375 deg. C. in order to carry out annealing in the most satisfactory manner. These figures may be deduced fairly satisfactorily from the various groups of test results given above.

The next slide shows the actual process of age hardening. It will be seen that the tests indicate the maximum temperature should be a little below that in order to obtain the stress of various samples of Duralumin which have been heated up to 490 deg. C., and then have been quenched out rapidly and allowed to age for the periods shown in the left hand column. The first test was made immediately after quenching, the material having been taken straight out of the quenching bosh to the testing machine. A strength of 16.5 tons per square inch was obtained. Thereafter tests were made at the end of various periods, and it may be seen that in 10 hours the maximum stress has increased by 5 tons per square inch, whilst after 24 hours the increase is 8.5 tons per square inch, and 10 tons per square inch after 72 hours. The material, therefore, has done nothing except increase in strength during that time, no external agency of any kind having been applied. It is customarily believed, however, that at the end of 4, 5 or 6 days the ageing process in Duralumin has completed itself. For all practical purposes this is true, but as a matter of actual fact it would probably be near the truth to say that in so far as our existing knowledge goes, the ageing of Duralumin is never quite complete. There is certainly evidence to show that after a lapse of ten years the material is still ageing slightly. The material may possibly increase by 1.5 or 2 tons in the course of a century, but in practice the change of properties occurring after one week of ageing are of scientific interest only, with one reservation, i.e., the effect on large masses.

If Duralumin is quenched out completely, that is, if a small piece is quenched right through and allowed to age, the ageing process will be practically complete in about a week. If, however, a mass, say 6in. thick, is quenched out, it will be impossible, of course, to obtain the same degree of quenching in the interior as at the exterior. The metal will be quenched in the centre but not so severely, and the ageing process will take relatively longer. The effect obtained will be appreciated by considering what happens when material is annealed. If a metal is cooled very slowly it will not age at all. If, however, it is taken up to 400 deg. C. and cooled at a moderate rate, say on the floor of the heat treatment department, it will be found that although the material is apparently annealed, it subsequently gets harder, i.e., it is very slowly age

hardening. The result is, in a large mass of metal, rather similar, i.e., the interior ages more slowly than the exterior. This, of course, may not be of great importance unless the component must be put into service immediately, but there is a secondary effect which must be emphasised.

The change in the mechanical properties of Duralumin is accompanied by a change in the volume of the material which alters at the same rate at the age hardening. Thus, relatively speaking, in a large mass of Duralumin, the outside ages too rapidly, and as the volume changes occur throughout the main the entire forging may begin to warp. This is what actually happens in large complicated parts over a period of time, and warping defects in large Duralumin forgings can almost invariably be referred to this form of hysteresis, i.e., to the slower age hardening of the lesser quenched portions. Fortunately this can generally be overcome by removing the excess metal prior to quenching, or allowing an adequate time to elapse after treatment before the part is put into service.

The next slide illustrates the annealing process which is carried out on pressings or similar articles, starting with material which is initially hard. In this case the most satisfactory softening is obtained at a temperature of about 400 deg C. Actually the temperature should be a little below that in order to obtain the best results.

With regard to alloys which do not contain magnesium, the heat treatment is rather different. Such alloys can be quenched out from approximately the same temperature as Duralumin, and in the same way, but they do not age harden at ordinary temperatures. In other words, the temperature of the atmosphere is not a tempering temperature for such metals as plain copper-aluminium alloys free from magnesium. The tempering can, however, be carried out by heating the metal up to 150 deg. C. Here again there is a close analogy with steel. For example, a plain carbon steel can be tempered at a very much lower temperature than a high speed steel. Similarly, Duralumin or the magnesium bearing alloys can be tempered at a lower temperature than copper silicon alloys, the age hardening in the former being in reality a process of self-tempering. Copper silicon alloys have not yet become of very great commercial importance.

The next slide illustrates a useful way of comparing the alloys of aluminium and other structural engineering materials. To find a suitable basis of comparison for materials of widely varying specific gravity is not particularly easy, and I think it is only a matter of convention that the basis adopted in the table is now being adopted so generally. This basis is the ratio between the fatigue strength of the material and the specific gravity of the metal. The quotient of these two quantities does provide

designers with a certain index of merit, and it may be seen on that basis that some of the aluminium alloys come out very satisfactory. The three wrought materials at the top are 35 ton steel, 55 ton steel and Duralumin, whilst at the bottom is Delta metal, which is a well-known brass alloy. On the basis of comparison adopted, it is better volume for volume to use Duralumin than 55 ton steel. Of course, Duralumin would come out at a lower ratio than 70 ton steel, which gives a figure of approximately 4.4 as against 3.7 for Duralumin. The Delta metal, as you will see, gives a hopelessly low ratio. On the same basis the various cast alloys have been included, those shown being the best cast aluminium alloys obtainable. It will be seen that they do not compare at all favourably with any of the other alloys for structural purposes. Unfortunately, cast iron was not included in the schedule, but if it had been it would have come out lower than any of the alloys shown. On this basis, therefore, light alloys can be regarded as serious competitors with steel for structural purposes. Anything requiring a maximum stress of not more than 60 tons per square inch can quite profitably be made in Duralumin.

Perhaps the most satisfactory example of the use of Duralumin is in automobile connecting rods. In some cars, of course, a 65 or 70 ton steel is used for connecting rods, and there is then no saving in weight in making the change-over to Duralumin. At the present time, there are between 30 and 35 different motor vehicles in which Duralumin rods are used or are being tried.

One may say in passing, that the use of a light alloy to replace steel is not such a simple matter as it might appear. Usually a number of secondary considerations are involved which actually accentuate the value of the lighter material. There are, of course, also disadvantages about the use of light alloys generally. All of them, for example, have a rather low melting point. In the case of the majority of light alloys of aluminium, the melting point is round about 540 to 550 deg. C. The exact temperature, of course, varies somewhat with the composition, but ordinary alloys containing copper begin to melt at about 550 deg. C. One can hardly expect, therefore, to use these alloys at any temperature over about 450 deg. C. This is a decided limitation, although up to 450 deg. C. the alloys behave fairly satisfactorily and retain their strength. Actually in the case of Duralumin, a metal which has a maximum stress of 26 tons at the ordinary temperature, will have a strength of 18 tons at 300 deg. C. and 7.5 tons at 400 deg. C. This figure may not seem very high but it is definitely known that in certain automobile or aero-engines, the steel valves at their actual working temperature have a maximum stress of only round about 5 to 6 tons per square inch. It is obvious, therefore, that the ferrous materials will work at such strengths quite satisfactorily, and equal results may be expected from light alloys.

The second point which must be mentioned is the question of corrosion on light alloys. Resistance to corrosion naturally varies somewhat with the composition of the alloy, but this is also true of steels. The highest resistance to corrosion is obtained in pure aluminium, whilst Duralumin and its related alloys come very close to aluminium. Moreover, the actual extent of the corrosion on light alloys is frequently over-rated. In so far as actual loss of weight on the surface is concerned, aluminium loses less than ordinary steel, and generally speaking the extent of corrosion is less in light alloys than it is in steel. We are so accustomed to see red rust on steel that scarcely any notice is taken of it, but as soon as we see white rust on aluminium we go mad and say, "This material is perfectly hopeless," instead of liberally coating the metal with some other protective coating. Aluminium alloys in this respect should receive the same attention as iron and steel, i.e., they should be protected against the effects of the atmosphere.

Discussion on Dr. L. Aitchison's Lecture on "Light Alloys."

The President, Mr. R. H. Hutchinson, in the Chair, in opening the discussion, said that Dr. Aitchison need have had no qualms about not being able to deal with the subject of machining, because from beginning to end of the lecture every word they had heard had been on a subject of very great interest to them as production engineers. Production engineers not only had to machine an article, they had to follow a part through, and many points, such as difficulties in casting, distortion, etc., arose. It was a great help to them to know something about these matters. There was one point which Dr. Aitchison had mentioned which had interested him very much, that was, the similarity between aluminium castings and iron castings. The point immediately came into one's mind as to the suitability of aluminium castings for jigs and fixtures, because in work of any size, a tremendous amount of labour was necessary in operating heavy fixtures, and this could be saved by utilising fixtures built up of aluminium castings. He had had some experience in this direction, although until two years ago he was opposed to the use of aluminium castings for fixtures. He had tried it, however, and apparently with quite satisfactory results. What he would like to ask Dr. Aitchison with regard to such fixtures was whether there was any likelihood of any greater movement in an aluminium casting than there would be in a fixture made from an iron casting.

With regard to the use of Duralumin, many of the members had had bitter experience of fixtures built up of mild steel, etc., and he wondered whether the same trouble would arise when using fixtures built up from forged Duralumin.

Dr. Aitchison had mentioned a slight variation in bulk of metals, but he was not sure whether this took place during the ageing process, or how long it went on, since the ageing seemed to go on for a very long time. On one slide in which the effect of quenching off when working on Duralumin was shown, the specific gravity was given as 2.82, and was the same before and after the quenching process. This seemed to indicate that there was no alteration in bulk, and one might safely presume there would not be much movement in a fixture.

Another point concerning the best method of heat treatment for casting which were to be used as fixtures. Would it be necessary to take such castings up to a temperature as high as 450 deg. C., or could they be heat treated to remove internal stress at a lower temperature than that?

Another point which he would like to know something about, was the exact internal process in the metal which took place to result in age hardening, and why the metal differed from steel in this respect. He would also like to ask Dr. Aitchison why the inclusion of magnesium made castings more difficult to produce. There must be a good reason for this. Was it because of the volatile nature of magnesium?

MR. H. ALLEN (Messrs. D. Napier and Son, Ltd.) said that he would like to congratulate Dr. Aitchison on the rendering of his subject. He was sure it had been most illuminating, and with regard to metallurgy they had learnt a very great deal. He would like to ask whether in the test results that were shown on the screen, the figures were taken from forged material or from cast materials?

Another question which he would like to ask was whether it would not be better in the case of many Duralumin components which had to be machined, if these parts were first rough machined, then heat treated after the rough machining, and the finish machining done afterwards. It occurred to him that one might get better results by treatment of Duralumin components after rough machining than in the original condition, as cast or forged.

MR. SHEWAN remarked that in casting aluminium, one frequently noticed epidemics of what they termed black specks, i.e., very fine pin holes. These come along at various periods. For instance, the castings for some time would be quite clear, and then, without any apparent change in the metal, these black specks would reappear in other castings. Was there any known explanation of this defect?

Mr. A. Willmott (Member) said he thought they had to congratulate themselves on such an excellent lecture on a very interesting subject. He was only sorry that he did not rise to ask any particular question. He was very interested in the subject of Duralumin as he had been associated with the early history and development of the first Duralumin to be made in this country This was done at Cheston Road, Aston, where he was more or less responsible for fixing up the first foundry and for entertaining the four German engineers who came over. They certainly had a very interesting time and a good many difficulties were overcome in that foundry in the production of the first bars of Duralumin One thing which struck him particularly at the time was that they could never induce the German engineers to disclose the critical details which were required, and some of the stuff turned out was not by any means Duralumin in the sense that this metal was known to-day.

In listening to Dr. Aitchison, he could not help remarking what tremendous strides had been made in scientific knowledge as well as in the practical applications of Duralumin since the days to which he referred.

Mr. Handforth said he thought that there was one casting alloy which was rather more important than the statements made in the lecture led one to suppose. In his opinion the copper silicon alloys were now playing a much more important part, particularly in America. He sometimes thought that in the aluminium trade, metallurgists could not altogether be proud of the progress that had been made. Since the end of the War, for instance, there had been very little improvement in aluminium alloys apart perhaps from the case of silicon alloys. No great improvement in aluminium alloys had been made for nearly ten years and as he had previously suggested, he thought it was time that responsible people got together and produced cast aluminium alloys or easily treated alloys, which were very much better than the present day metals.

There was one question he would like to ask Dr. Aitchison with reference to the extent to which Duralumin was being used for connecting rods. He had recently heard various arguments on the merits of Duralumin connecting rods, in view of the different opinions expressed and he would like to know whether they could take it definitely that Duralumin connecting rods were satisfactory for cars. Another point bearing out the same question was had it been proved yet whether the fatigue range of Duralumin is a constant figure? He had heard of one metallurgist who maintains that the fatigue limit continually decreases whilst other metallurgists say that Duralumin has constant fatigue limit just as steel. It was interesting to note that Dr. Aitchison said that

the ageing of Duralumin never came to an end, so it was possible to believe that the loss of strength never came to an end in the same way.

With regard to the warping which occurred in Duralumin after machining, it is not necessary for pieces to have to be 6in. or even 4in. thick for the warping to be noticeable. He would remind the President of the behaviour of certain bearing cups of which the section was less than 1in. thick and in which considerable distortion after machining had been noticeable on many occasions. Sections which when drop forged were not much greater than 1¼in. thick had also been found to change considerably and to give trouble through distortion when first machined.

Magnesium light alloys had not been discussed very much in the lecture, but he thought that the physical tests now obtainable justified rather more attention to magnesium alloys. It was possible nowadays to obtain with such alloys, test figures approaching those of Duralumin, with, in the case of magnesium alloys, a very much lower specific gravity. Extruded magnesium alloy bars could be obtained with a strength of 22 to 24 tons per square inch, as compared with 26 tons for Duralumin.

Without entering into a metallurgical discussion on Duralumin it was interesting and somewhat amusing to note that whilst its capacity to harden was generally believed to be dependent on magnesium silicide, the ordinary specifications for Duralumin made no mention of the amount of silicon to be contained in the metal.

With further regard to the chemical composition of Duralumin he was pleased to be able to comment upon the wonderful regularity with which this material was supplied by the firm with which the author was connected. During the last four years he had seen careful examination made of a very large number of deliveries of this material and in no single instance had the chemical composition of the material been outside the limits of the speicification to which the material was ordered. This regularity of composition was a very satisfactory feature of Duralumin.

Mr. Gerard Smith (Member of the Council) said we had learnt so much from the lecture that it seemed almost greedy to ask for more. Two things interested him in particular. It seemed that the temperature range through which one could usefully employ Duralumin and its alloys was not a very wide one, and in the case of a connecting rod for a car or aero engine, there might be conditions when the temperature ranged from below freezing point in water up to some uncertain but fairly high figure. Again in airship construction there might be extremely low temperatures due to high altitudes alternating with the sun temperature in tropical climates. It would be interesting to know whether repeated fluctuations of temperature over such ranges had any effect on the materials.

He rather regretted that Dr. Aitchison had not said anything about the effect of die casting, particularly as this process seemed to be quite an important one on these alloys. He had had some very beautiful die castings made in aluminium bronze, but these castings varied in physical properties. There might be some inherent difficulty in producing them. They were, however, so much better than ordinary aluminium die castings that he was surprised they were not more extensively used. Perhaps Dr. Aitchison could tell them whether there were specific difficulties which rendered the use of aluminium bronze die castings undesirable.

MR. SHEWAN asked whether there was any great difficulty in carrying out the forging of Duralumin as compared with steel. He had had a certain amount of experience of these forgings, and possibly had found that flaws were more prevalent. This was accounted for by the fact that one knew more about the stampings in steel, how to do away with cold shuts, and other defects. In forging Duralumin, they did not seem to have eliminated flaws to the same extent that they were doing in steel. This might be due to inexperience, or was it to be attributed to an inherent defect in the metal?

MR. HUTCHINSON said he would like to put one or two other questions. First, of course, he had to agree with Mr. Allen and others who had complimented Dr. Aitchison on the wonderful lecture he had given them. It was a very different thing from listening to pages and pages of a set paper, to have the privilege of listening to one who was absolutely master of his subject, and could speak authoritatively from personal experience and knowledge.

Mr. Shewan had referred to black spots in castings. He felt sure that someone would mention the subject, because in dealing with aluminium castings they had all had troubles of that sort. As Mr. Shewan had said, they came in epidemics; sometimes they might not come for weeks, sometimes not for months, and there would be no trouble. Then all at once every casting seemed to be covered with specks. Different foundries seemed to suffer in the same way, so that it would almost appear as if the trouble were due to some inherent defect in the aluminium billets used by the foundry, rather than to any particular method employed in the foundry. He would be interested to hear if that were the case, whether the black specks were present in the raw aluminium which came into the country; also whether Dr. Aitchison knew of any successful steps which had been taken to do away with this trouble.

There was one rather interesting point which he had noted in this connection. Some time ago he had had occasions to carry out some experiments in turning aluminium with a diamond tool, and he had noticed several times after samples had been turned with this tool, small oily specks appeared on the surface of the

aluminium. On the first occasion when this occurred he went to the man who had carried out the work because he had asked him to keep the sample particularly clean and clear, and there was no oil in the vicinity. This man said the aluminium had been wrapt up in a clean cloth, and he tried the work again when it was possible actually to watch the oil specks exude from the metal. They came out just like small bubbles and gradually spread over the surface of the aluminium and dried, and when they had dried they gave one a very clear impression of the same black specks. Examined under a glass one found a small pin prick in the middle of the specks. He wondered, therefore, whether there was any relationship between the fluid which exuded and the black specks. Whether, for instance, the black specks were not a result of the combustion of the fluid. This seemed to be borne out by the fact that when small bright sparks could be seen flashing out in making an aluminium casting, it was almost certain that there would be black specks in the casting. As castings are sometimes scrapped after machining on this account some information on this point would be of very great interest.

Mr. Shewan had mentioned the matter of flaws in Duralumin forgings, and he had heard this explained by the fact that there was a discontinuity of structure in the Duralumin. He would like to know whether this discontinuity was brought about by the working of the metal, or whether it might be due to weak fibres in the material which gave way under strain of forging? Another thing, did Duralumin harden very rapidly under cold working, or did it get brittle on the surface, and was one likely to form a surface by cold working which would be liable to set up minute cracks or flaws? This was an important point in highly stressed parts. It had also occurred to him in connection with difficult casting alloys, such as magnesium alloys, whether is was not possible to introduce some element into the alloy which would reduce the melting point just sufficiently to enable sounder castings to be produced?

He would also like some further information about Beryllium. Previously he was rather ignorant of this metal, but he felt comforted when Dr. Aitchison went on to say it was a metal very few people knew anything about.

Dr. Aitchison, in reply to the various speakers mentioned, said that he was obliged to them for the interesting discussion, and as far as possible he would take the questions raised in order. The first point concerned the permanence of dimensions of aluminium alloys in connection with jigs and fixtures. Of course, cast alloys and wrought alloys had to be regarded somewhat differently. Those cast were not in general subject to heat treatment, and were tolerably permanent in their dimensions when they were heated. Duralumin, however, would not be used

as cast as it would have to be forged and machined. The resulting material would, after an ordinary ageing period, be adequately permanent in its dimensions.

The specific gravity figures, to which reference had been made, taken on the alloy before and after heat treatment, did not give any reliable indication of the change during ageing, because they were not determined with sufficient accuracy. The change of dimensions in any case would be of the order of the thermal expansion of the material, and the actual change was an expansion in passing from the soft to the hard state during ageing. He was sorry that he could not give the actual figures, but the volume change was very small, and the only reason that it was important was the effect it had in warping the metal in large masses, due to the differential expansion between various parts of the material when one portion was softer than the other. When a metal expanded it would burst almost anything, and enormous internal stresses might be set up in a large mass with consequent distortion.

The question was asked as to the best annealing temperature for cast aluminium alloys for removing internal strains. It should never be necessary to heat aluminium alloy castings to more than 350 deg. C., and two or three hours at this temperature should put the material into a state of normal freedom from strain.

The question as to how the actual hardening of Duralumin occurs might lead to a very long discussion, and if he were asked the difference between Duralumin and steel in respect to age hardening, he would have to reply that he did not know. Moreover, it was doubtful whether anyone knew definitely why Duralumin hardened, although there were various ideas on the subject. What was quite certain on the matter, however, was that compounds both of copper and aluminium, and of magnesium and silicon, were formed in these alloys, and that both these compounds were more soluble in aluminium at high temperatures than at low temperatures. If, therefore, the material were heated up to a high temperature, one obtained a comparatively strong solution of these compounds in aluminium, just as more sugar would dissolve in hot tea than in cold. If the tea dissolved the maximum amount of sugar at high temperature, and was then allowed to cool, the sugar would come out of the solution and remain at the bottom of the cup. Similarly, if Duralumin were taken up to a high temperature, a comparatively strong solution of the silicon magnesium compound would be obtained, and if it were cooled so rapidly that the compound had not a chance to come out of solution, the result would be a supersaturated solution at ordinary temperatures. As, however, the temperature of the atmosphere happens to be a tempering tem-

perature for the metal, some of this dissolved material would come out of solution in a finely divided state. Those he thought were the probable facts, although this admittedly did not provide the reason for the actual increase in the strength of the material.

Another question was asked as to why the casting of magnesium was so difficult. The main difficulty was that magnesium had an exceedingly high affinity both for oxygen and nitrogen, and it also had the property in the molten state of occluding gases and expelling them when the metal became solid. Those were the main difficulties.

From all the work he had personally carried out on the subject, it appeared that the whole question of successfully casting magnesium devolved upon this property. All methods for casting magnesium were only really satisfactory in so far as they provided for the protection of the metal from the atmosphere, particularly whilst it was poured into the mould.

Regarding the test figures referred to by Mr. Allen, the test results were obtained on cast specimens when he was speaking of cast alloys, whilst for Duralumin the figures were taken from tests on extruded bars approximately 1in. in diameter. He, personally, was rather strongly in favour of the rough machining of forged Duralumin parts prior to heat treatment. Before the final heat treatment he thought it was always desirable, as far as possible, to reduce the thickness of any article which had to be quenched. He did not believe that annealed Duralumin was quite so comfortable to machine as the heat treated material. The 15 ton alloy in its soft state was considerably more "laggy" than the heat treated metal.

Both Mr. Shewan and the President had raised the question of black specks in aluminium castings. There were several kinds of black specks commonly found in aluminium castings, and one kind very frequently found consisted not of black specks of foreign matter, but of minute cavities which appeared black because it was impossible to see into them. The crystals of the aluminium alloy pulled themselves apart during the casting, and left tiny cavities all the way round. He did not think any aluminium casting of any size was entirely free from such holes; they were there, whether the castings were made in sand or in a chill mould, or whether the metal was cast into ingots. There was, however, a black constituent which was often found in aluminium, and which might arise from two separate causes. An excess of iron gave black specks in aluminium, and although such an occurrence was quite an ordinary thing, these specks should not occur if the material were made from virgin metal and the metal carefully watched. The use of scrap very frequently gave rise to these defects. The third cause of black specks was one frequently overlooked, i.e., carbides, and that probably was the explanation

of the exudation of the oily material referred to by the President.

Aluminium alloys had many reactions with carbon, resulting in the formation of carbides, and although the alloys would take up carbon in the molten condition, they did not hold the carbide in solution after becoming solid. It was, therefore, quite an ordinary thing to find a quarter per cent. of free carbon in cast aluminium. The carbon was not in solution beyond 0.05 per cent., the rest of it being free, and he had frequently been able to isolate black particles which had proved to be carbon compound in the material. Carbides were extraordinarily funny things, and he was not prepared to say what might happen if the raw material contained a quantity of carbides. Really, it was just a question of the world's supply of coal and oil being repeated on a very small scale. That perhaps was a tentative view, but it was based upon a certain amount of experimental evidence. As he had inferred, black specks might arise from a number of sources.

He was very interested in what Mr. Willmott had said, and would pass on his remarks to other quarters. Mr. Willmott would probably be interested to know that a certain number of men who were engaged at Cheston Road in the early days were still engaged in making Duralumin. He did not think, however, that there were any of the original foundry appliances still in use, showing that the manufacturing side of Duralumin, at any rate, had progressed somewhat during the 16 or 18 years that had elapsed since the days referred to.

This brought up Mr. Handforth's remarks regarding improvements in Duralumin. Mr. Handforth's complaint was quite a serious one when viewed from his standpoint, although, of course, one might conjure up another picture altogether. Aluminium had only been a commercial article for 25 years; the consumption of aluminium he believed in 1902 was 14 tons, whilst last year the world's consumption was 400,000, which indicated a tremendous increase in a comparatively short time. He did not know that it would be fair to expect an equally enormously rapid technical improvement. After all, 25 years was not relatively a very long time to do as much as had been done. One might say iron and steel had been known for a very long time. Tubal Cain used it. People in Delhi built columns, but unfortunately they allowed them to rust, and it was over 3,000 years later before the world discovered stainless steel.

RATEFIXING.

By Mr. Ronald (Member), at the S.M.M.T. Council Room, 83, Pall Mall, S.W.1.

May 27th, 1927.

I appreciate the opportunity of speaking before you on a subject which has not been discussed at our Meetings as fully as its importance to the subject of Production Engineering deserves.

I believe there are here to-night some who have devoted years to the study of our subject, consequently it is with some diffidence that I make the following observations.

I make them because between the paper and the discussion, information helpful to our younger members who may have occasion to fix rates, may eventuate. Also, it may enable some of our members who, whilst not actually interested in the subject, have to include the ratefixer and his duties as part of their managerial responsibilities, to appreciate some of the difficulties which confront him in his work.

I want to emphasize one thing. In this age of slogans—the Ratefixer's should be: "You cannot be too careful."

The ratefixer deals with money—his employer's money—and carelessness, ignorance or lack of thoroughness, result in loss. Loss to the employer, the employee, and the ratefixer; and the loss of the last-named is, if nothing worse, a loss of prestige.

The accumulative effect of bad ratefixing on the morale of a shop or factory is beyond computation. It may mean the difference between "The Official Receiver" and "Shares at a Premium." Bad ratefixing may be either too generous or too parsimonious. The ultimate effect is the same in each case.

Before outlining the ratefixers' difficulties, I had better define a rate as I wish it to be understood throughout this paper and as it is generally understood in the Engineering World, i.e., its specialised meaning as distinct from an hourly or weekly rate fixed by employers and employees trade combinations.

A rate then is "The Evaluation of the unit of time required by an average workman to perform a piece of work."

To this may be added various allowances for bonus or piecework purposes and various other factors which at this stage do not affect the question.

This definition reveals in some measure wherein the ratefixer's difficulties arise.

He deals with variables, the three controlling ones being:—

(a) The man.

(b) The material.

(c) The machine.

His, then, is not an exact science—he cannot apply to text books for formulae neither can he fix a rate from a ready reckoner. But he can build a rate as surely and as accurately within its own purview from data based on the results of motion study in the case of the man and the machine, and on speed, feed and cut combinations in the case of the machine and material, as Euclid built his problems and theorims, from definitions, axioms, and postulates. It is my object to outline methods found suitable for this purpose in my experience.

Before doing so I will enumerate the qualities required to make an efficient ratefixer:—

(1) He must have a practical knowledge of the trade in which he intends fixing rates.

(2) He must possess the faculty of analysis in a highly developed degree.

(3) He must be temperamentally precise and careful.

(4) He should possess a sound technical education, particularly in the mathematical and mechanical subjects pertaining to his trade.

(5) Above all; a knowledge of psychology is indispensible.

One hardly expects to find all these qualities in a young man, so the wise manager rarely looks to the ranks of the "Young man in a hurry" to provide him with an efficient ratefixer. Natural qualifications as to temperament, acquired qualifications as to practical and technical ability and experience in dealing with men —these are the ratefixer's stock-in-trade.

The title of this paper may be taken literally, but the subject matter will be confined to the art of fixing rates in the machine shop. The principles and methods outlined and illustrated are applicable to any industry or handicraft. It is, however, advisable to define the limits of this paper to prevent disappointment because the ratefixer, as a cog in the industrial wheel, may have to perform duties in addition to fixing rates, so diverse as:—

(1) Shop supervision in which he is responsible for production as well as ratefixing.

(2) Processing or determining the sequence of operations.

(3) Routing work to appropriate machine tools.

(4) Planning layouts with determination of jigs and tools.

(5) Setting and controlling feed, speed, and cut combinations.

(6) Progressing work through the shops and a multiplicity of allied duties.

None of these duties come truly within the gambit of the ratefixer, as such; and no attempt will be made to discuss any

of them in detail. Nor will any attempt be made to discuss methods of payment such as bonus, premium, or piecework systems. I may remark, in passing, that it is strange that so many papers, articles, and even treatises have been written round such systems yet so little useful information has been published on the actual fixing of the rate, when it is realised that the system of wage reckoning does not matter if the primary evaluation of the time necessary to complete a unit of work is correctly computed. It is not too much to say that the justification of many of these systems is that they nullify the results of bad ratefixing by methods of mathematical jugglery or by means of logic based on questionable premises. A special point bearing out this was made by the late Mr. James Rowan in, I think (I quote from memory) his paper on the Rowan Premium System read at the Institute of Mechanical Engineers in 1901 or 1902. We find all kinds and combinations of wages systems covering in their effect, and often their intention, all kinds of ratefixing, bad, indifferent, good—the two classic instances of the first and last mentioned being the Rowan Premium System, and the Halsey Bonus System. Is it too much to say that if we could ensure accurate ratefixing all of these artificial wages systems might be abolished? Then, with satisfaction, we might parody Tennyson and say: "All these systems had their day. They had their day and ceased to be"? A consummation devoutly to be wished, but what would replace them?

An hourly rate with an equivalent unit of work accurately determined by the ratefixer. I cherish the hope that this method of payment may in the near future become general instead of as at present, exceptional. I will not attempt to deal exhaustively with the historical or economic side of the subject. As to its antiquity—there is no record. One would not be surprised, however, if records were found proving the existence of a Ratefixing department on the site of the Tower of Babel. At any rate, the following extracts show that in England definite means were employed to fix rates on definite bases as early as the year 1574. "In this year at the Mineral Battery Works factory at Tintern, Monmouthshire, the workers for the most part were paid on a piece rate basis. The rate for straining iron into rods was 1s per cent. Drawing 3d. to 10d. Ripping 4d. Slipping 1s. per cent. The wages of smith and striker amounted to 8s. per week. Carpenter and his labourer 5s. The Nealer and his assistant 7s. 6d." The diet of a person for the same period was reckoned at 2s. per head.

Bonus as well as piece rates were often given as the following abstract from the Company's book shews.

"T. Wallner, Foreman and copperer is promised when 1,000 cwt. of copper shall have been made, £2 5. 0. The period he

took to complete the task was 20 months from April 30th, 1568, to January 1st, 1570." His wages were 13s. 6d. per week, his bonus therefore during this period amounted to 16 2/3rds. per cent."

These extracts show that rates were fixed with some degree of exactness in England prior to the Industrial discovery of America.

This being so, I crave to be excused the usual panygyric on things American as well as the usual jeremiad on the decadence of Industrial England, particularly its Engineering decadence ; for I do not believe that this England of ours is failing to progress.

I also hope that admirers of what is commonly known as The Taylor School will likewise excuse my omission of any reference to it except to say that all signs point to its being, if not defunct, at least dormant.

During the past twenty-five years I have interviewed many applicants for posts as ratefixers ; almost invariably I have been informed that the applicant possessed a large amount of Data, and almost as invariably have I advised him to keep it at home or destroy it. Why? Because data accumulated in one shop is rarely useful in another. Indeed, in the hands of an unskilled ratefixer it is a menace.

What then is necessary to the Ratefixer in the way of Data to enable him to fix rates in any given shop?

(1st.) Particulars of the correct (economic) speeds, feeds, and depths of cuts for each class of material used in that shop.

(2nd.) Particulars of the possible speed, feed and depth of cut combinations of each machine tool he is dealing with.

(3rd.) Particulars relative to the time necessary to perform any action connected with the operating or setting of each machine tool.

In (1) two things have to be considered:—

(a) Due to the multiplicity of new alloy steels and the great number of non-ferrous metal alloys now used in manufacture how shall the ratefixer acquire a knowledge of appropriate feeds, speeds and cuts? Definite data can only be obtained by actual tests.

As to whether these tests are conducted by the ratefixer or an official specially detailed for the work, depends upon circumstances. In a large factory producing a varied class of work, I cannot too strongly express the opinion that a section of the planning department dealing with shop efficiency should be responsible for this work. To this section should be relegated all questions relative to machine tool, small tool, and jig and fixture efficiency.

(b) How, when he has acquired this knowledge, shall he coordinate and keep it so that he may use efficiently the tool thus provided? There are many methods. The aim should be to keep such records in a form most suited to quick and accurate reference. I have found the form illustrated on the chart marked (A) as convenient as any. I desire to make it clear that all charts, etc.,

are shown only as illustrations of methods or principles. Most of them are ancient and I do not presume to show them as usable data.

(2) Feed and speed combinations of various machine tools.

It has been shown by Chart A that a graph may be prepared covering the machining limitations as to feed, speed and depth of cut for any given material. The chart for any given machine tool is similar in construction, but gives time equivalents for any given combination of feed, speed, and cut capable of being used on the particular tool from the basis found on Chart (A). As an illustration:—

It is proposed to take a cut 3/16 in. deep across a .3 carbon steel bar 3 in. dia. x 2 ft. long on a lathe having the speed and feed capacities shewn on Chart B.

From the A type Chart applicable to .3 carbon steel is found the economic speed in feet per minute and the feed, in traverse per revolution for a depth of cut of 3/16 in. The diameter of the work is translated into feet per minute, the ratefixer using the ordinary type of circular slide rule for this purpose. Applying the figure so found to Chart B he uses the line of times found on this chart nearest or immediately below the number of revolutions shewn on Chart A and where the length of work ordinate cuts this line the time taken is found at the feed ordinate nearest to or immediately under that given on Chart A.

On these charts then, cutting lines for varying diameters and materials may be constructed such that the resultant time for any given cut on any given material may be found immediately at the intersection of the ordinates.

These charts A and B, in combination with the slide rule, become the ratefixer's tools for working out what I shall term "The machining units" on a piece of work.

The information possessed by the Ratefixer should be at the disposal of the operator in a modified form. The reason for this should be clear; yet by many it is not understood or appreciated. How many machine minders have any idea of the most efficient cutting speed and feed for a given metal? Yet it is expected of them that they shall produce work to a time schedule without any enlightenment as to speeds and feeds whatever!

It is not necessary to give this information in values. A card attached to the machine shewing diagrams of feed and speed pulleys with the particular speed and feed for any given cut is all that is required. Inability to use the scheduled speeds and feeds provides a means of adjusting times or making allowances for hard material, etc.

(3) Particulars as to the time necessary to perform any action connected with the operating or setting of each machine tool.

Here the ratefixer is confronted with his most difficult task

In analysing an operation on a piece of work the machining units have to a great extent been found for him. The surfaces to be machined are determined on the drawing of the part. The applicable cuts, speeds and feeds are shewn on Chart A for the material. The capacity of the machine tool is shewn on Chart B, but the handling units must be determined. The only method of determining values for these units is by Motion Study.

I want to make it clear that in dealing with Motion Study at this stage I am dealing with its application to the determination of the time values of the various motions required to operate the Machine Tool—not the motion study of the time values necessary to complete a given operation on a piece of work. I will refer to this later.

It is immaterial whether these units are determined by the Ratefixer or by an independent official attached to the Planning Department. The essential thing from the Ratefixer's point of view is that they truly represent unit motion time values based on the performance of the average operator. I may remark that the average operator is a purely hypothetical individual, but it may be of interest to describe the method followed by me and which I found entirely reliable, in evaluating this individual, and so arriving at these units.

1st. I analysed with the assistance, wherever possible, of the maker's specification, the machine tool and tabulated all the motions necessary in setting and operating it.

2nd. I took a number of motion studies—generally three of each motion—and endeavoured to have these repeated by three different operators.

3rd. I averaged the results.

These averages I termed "Handling and Preparation Units" and considered them as representing the capabilities of the average operator. As many of these units only occur during preparation or, in other words, during the setting of the machine preparatory to producing the work, I differentiated where necessary on the Chart a portion of which is shown in Table I.

These charts comprise the chief data required by the ratefixer in setting a time value on any given machining operation. With the drawing of the part in front of him he proceeds to make his analysis of Preparation, Machining and Handling Units and when this analysis is finished it will be noted that the ratefixer has completed the job mentally. In other words, he has envisaged each necessary motion of man and machine in completing the work. It is here that the ratefixer's practical knowledge is indispensible. Obviously, the ratefixer must know how to do the job before he can say how long it ought to take to do it.

Tables 2, 3 and 4 show a complete analyses of machining operations. The sum of the handling and machining units repre-

sents the actual time the average operator ought to take to complete the given operation on one piece of work. This figure into the number of hours a day would represent the number of pieces completed by an operator giving an efficiency of 100 per cent. But 100 per cent. efficiency can only be achieved by the super machinist and the ratefixer has to figure on something less than this. Therefore, on the analysis a column or space is left for figuring this efficiency and making the allowance. As to the method of arriving at figures which are in any way reliable I can only speak with authority on a range of operations covering times from five seconds to 120 seconds. The tabulation of these figures occupied me for a period of six months and were based on daily outputs from a department of a large factory entirely run on a piecework basis and producing small repetition work in very large quantities. The results are shown on Chart C. Very clearly is shows the fatiguing effect of rapidly repeated motions. A good deal of work has been done by various investigators along this line and I must refer members to the works dealing with the subject. Nevertheless, a ratefixer must, no matter what the duration of time of the work he has to rate, take into account fatigue, and only by observation, motion study, and close tabulation of results can he arrive at reliable figures. As to the various allowances which require to be made covering machine oiling, personal service, etc., these all become part of the calculation in arriving at the efficiency factor. As an item of interest it may be mentioned that an "Oiling" chart was prepared. This was used as part of my stock in trade in arriving at an Efficiency factor or small automatic machines operated in gangs. The operatives were, in this instance, expected to oil their own machines.

I have shewn how a rate for a single machining operation can be accurately calculated. The method takes time and I now propose shewing how on a given line of similar operations, on similar parts, on similar machines, the work varying as to dimensions, the task of calculation can be practically cut out. I shew two methods. The first method, which I recommend, shews a chart constructed principally from motion study units. The second—which is useful under conditions where meticulous accuracy is not an essential—shews two charts constructed from actual performances carried over a line of similar operations, on similar pieces, machined on similar machine tools.

The first method is shewn on Chart D and Table 6 which gives an analysis. This analysis was made 13 years ago and covered a gang of small Parkinson hand operated internal grinding machines principally used to grind jig and other bushings. The actual grinding times are not of any value except when used under identical conditions to that obtaining when I constructed the charts, but the method may prove of some value.

CHART D.

This chart is an attempt to determine rates for internal grinding in such a manner that the following conditions will be fulfilled.

1st. Consistency in ratefixing.

2nd. Modern practice.

3rd. Average conditions obtaining in Grinding Dept.

4th. Full and due consideration of all known factors entering into actual grinding of a piece of work.

Considering the variety of work of this class passing through the shop, we find these varieties resolve themselves into,

1st. Work that can be set on jigs or adaptors.

2nd. Work which must be chucked.

3rd. Work which entails setting methods.

Again, if we take any piece of work we shall find that the completed operation consists essentially of the following factors, all of which vary either in respect to the size, tolerance, shape or other peculiarity of the piece.

The factors are as follows:—

(a) Setting.
(b) Grinding (actual machining only).
(c) Gauging.
(d) Removing
(e) Truing up grinding wheel.
(f) Fatigue factor.

In regard to the setting on the first variety of work, i.e.. that which can be set in a jig or adaptor, we have taken as an index of the general run of work in the shop, a constant of 60 seconds. This time is based partly on the following analysis of the essentials necessary in this class of setting.

1st.	Lift piece from floor and put in adaptor ...	10 secs.
2nd.	Screw up, say, 3 bolts at 10 secs. each... ...	30 ,,
3rd.	Start machine	7 ,,
4th.	Bring wheel up to mouth of hole	8 ,,
	Total	55 secs.

There we have a fair general statement of the motions necessary before actually starting to grind a piece. With the exception of the second all may be classed as constants. The second will, owing to the difference in shape of the piece, vary somewhat, but in very few cases will there be more than three bolts to screw up, in fact, in the majority of cases, one bolt, wedge or other clamping arrangement will be sufficient.

It will thus be seen that 60 seconds should be sufficient to cover the majority of cases.

In regard to work that must be chucked, this work principally

consists of bushes which are ground both internally and externally. In such cases the internal grinding is done first to allow of the external being finished on a mandril, thus ensuring concentricity. When the part is received in the Grinding Dept., only sufficient material is left on the surface to be ground to ensure the work cleaning up, experience having shown that it is more economical in time to leave the minimum amount of material and spend some time truing up the work, than to leave sufficient material to simply chuck the piece in the chuck jaws and depend on the amount of material left to clean up. Hence we have here an additional factor to consider, i.e., the truing up of the piece. In analysing the necessary factors we have :—

	mins.	secs.
1st. Lift piece from floor and place in chuck ...		10
2nd. True up piece dividing when possible the concentricity between the outside and inside surfaces	1	30
3rd. Tighten up chuck jaws		30
4th. Start machine		7
5th. Bring wheel up to mouth of hole		8
Total	2	25

As in the case of the jig work all the factors with the exception of the second, may be classed as constants. The second, however, is liable to vary considerably because some pieces are much more difficult to true than others, due to normal variations in turning, as well as in hardening.

It has been considered inadvisable to fix any unit for setting the third class of work. The difficulty of approximating on this class of work will be understood when we consider what may be termed compound pieces, e.g., a piece of work with two holes parallel to each other with a very close limit between the axes of the holes. In this case there are three problems to face.

1st. Setting the holes parallel.

2nd. Setting the correct distance between the axes.

3rd. Getting the holes right to the diameter required.

No matter how perfect the fixture, a considerable amount of skill, as well as time, must be used to prevent scrap being made.

To cover such cases, the setting factor has been left entirely to the judgment of the ratefixer and a chart made to cover all the work necessary, with the exception of setting.

We have now shewn what has been done in regard to setting work and the next point is the method of dealing with the manufacturing limits. It will be granted that the limits, or closeness of hole to absolute, influence the care (which we may translate into time) necessary in sizing. It is extremely difficult to evaluate this because it is here the human factor exercises the greatest influ-

ence. It is well known that one operator, confident and resourceful, will grind a hole to a half-thousand limit as quickly as a hesitating, uncertain operator will grind a hole to a one thousand limit. To deal with this we must eliminate the factor of variable operators and postulate a hypothetical standard of efficiency in the operator. This standard can be arrived at by averaging a sufficient number of results from motion studies made on the performances of a number of operators. This done, we are able to fix arbitrarily varying grades of work requiring differing degrees of skill, as under :—

1st. Tolerance less than .001 in.
2nd. Tolerance of .001 in. and including .002 in.
3rd. Tolerance over .002 in.

It was decided to make .001 in. the standard tolerance for the purpose of this chart and all tolerances from .002 in. to .001 in. are considered standard. Tolerances greater than .002 in. are valued as 80 per cent. of the actual grinding time and under .001 in. as 140 per cent. These are purely hypothetical ratios but are as near actual values as it is possible to estimate.

Another factor entering into the question of time necessary to grind a hole is the question of the amount of material left in for grinding.

In soft work it is possible to standardise this within limits, in which our charts could be made to suit the small size, but in hardened work it is not possible owing to the variation caused by hardening. To enable due allowance to be made for this variation, the standard chart has been made to suit an allowance of .012 in. in the hole, and the inspection department have instructions to declare on the work tally the number of pieces in each batch exceeding this amount, at the same time specifying the actual amount of material to be removed. Allowances of .010in. or less are reckoned as standard. By this means the foreman grinder can requisition the ratefixer before the commencement of a batch for additional time allowance for excessive material.

Taking into consideration that less care (and consequently time) is necessary to remove material above the .010 in. standard, the basis for removing excessive material has been fixed as under :—

$$\frac{\text{ACTUAL TIME TO REMOVE .001 in. at standard}}{3} = \text{Time to}$$

remove .001 in. over standard.

The next factor to be dealt with is the question of gauging.

Very frequent use must be made of the Plug gauge when grinding a hole as this is the most convenient means of sizing. It has been found by experience and observation that the gauge must be used, on an average, about nine times before the size is arrived at and the average time to gauge is about 10 seconds.

TABLE 1.

UNIT OPERATIONS. HANDLING TOOLS AND MACHINERY.

Standard Data, No. 16. Herbert Combination Lathe.

No.	Operation.	Prep. or Handling.	Min.	Sec.
A	Lifting bar from rack, carrying to machine and securing in chuck	P & H	2	30
B	Changing chuck jaws, hard to soft or vice versa	P	3	0
C	Securing round blank to be operated upon in chuck ...	H	—	15
D	Putting in and securing service stop in chuck, from store	P	—	25
E	Feed bar out to stop and secure in chuck	H	—	45
F	Taking off and putting on chuck, includes going to store	P	5	0
G	Putting on and bolting up square turret to chasing saddle	P	5	0
AU	Getting job with instructions, varying from 1 to 5 minutes	P	—	5
AV	Cleaning down machine	P	5	0
AW	Writing out line for tools and going to store for same ...	P	5	0
AX	Filling-in Time Card	P	2	0
AY	Looking out bolts, glands, packing-pieces, etc.	P	5	0
AZ	Rounding corners with file—per edge	H	—	10
BB	Setting and trueing up casting in chuck—simple ...	H	5	0
BC	,, ,, ,, ,, medium ...	H	10	0
	No. 15.			
BD	Setting and trueing-up casting in chuck—difficult (includes lifting from floor to machine)	H	15	0

TABLE 2.

UNIT OPERATIONS. MACHINING AND HANDLING.

Key Letter.	Unit.	Machining. Min.	Machining. Sec.	Handling. Min.	Handling. Sec.
BC	Set-up and true casting in chuck	—	—	10	0
T	Adjust speed for facing	—	—	—	15
L	Adjust feed	—	—	—	5

TABLE 3.

UNIT OPERATIONS. PREPARING.

Key Letter.	Unit.	Machining. Min.	Machining. Sec.	Handling. Min.	Handling. Sec.
AN	Getting job with instructions, etc.	—	—	5	0
AN	Writing out order for tools and going to Stores ...	—	—	5	0
AY	Looking out bolts, glands, etc.	—	—	5	0
H	Putting in tool in square turret (stops) (F)	—	—	6	30
Z	Cutting in C tool	—	—	1	0
AC	Put on and adjust S.& bar	—	—	2	30
AD	Put in drill and reamer (2)	—	—	3	0
AT	Put in chuck bushing	—	—	2	45
AK	Remove chuck bushing	—	—	—	30
AK	Remove 7 tools (½ minute each)	—	—	3	30
AK	Write out time card	—	—	2	0
AV	Clean down machine	—	—	5	0
	Other small items, 10 per cent.	—	—	5	12
				55	57

Part No. 2222L.

CHART D.

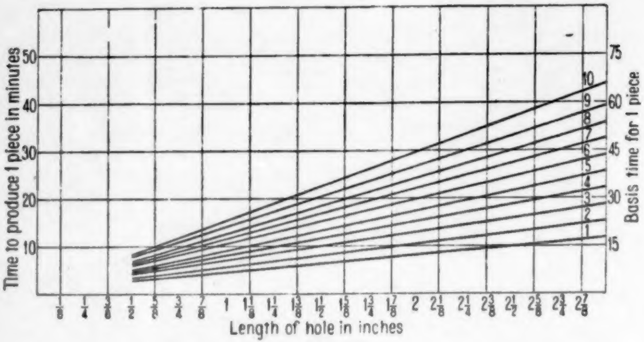


CHART A.

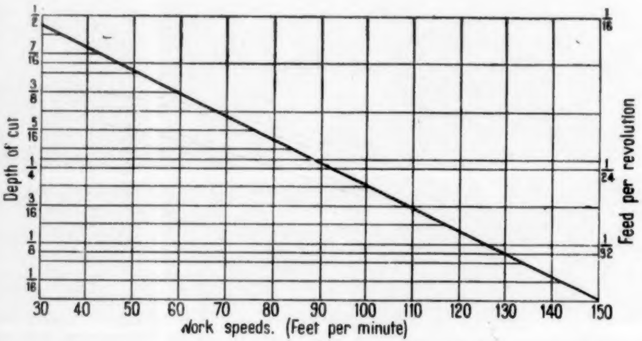


CHART E.

CHART F.

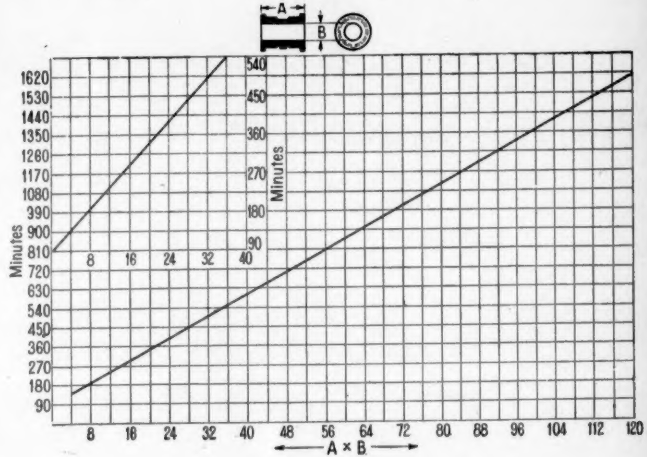
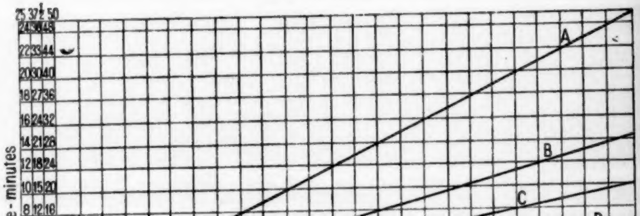


CHART B.



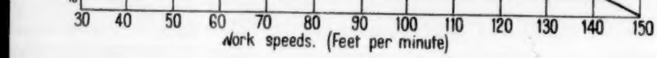


CHART E.

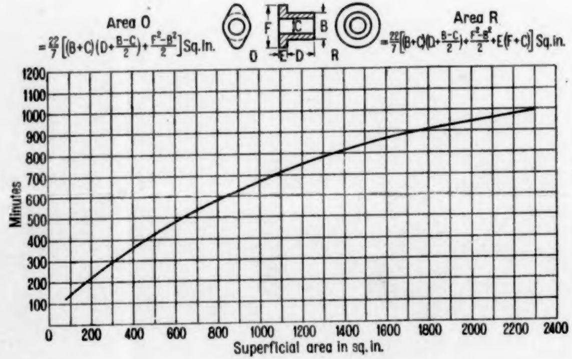
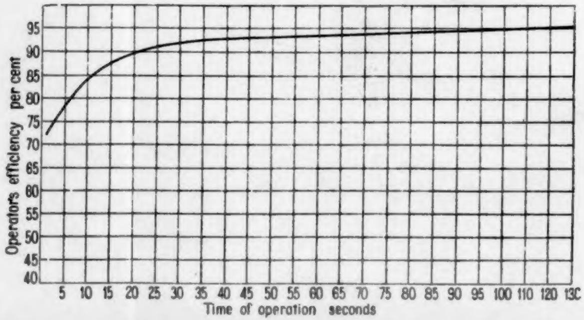
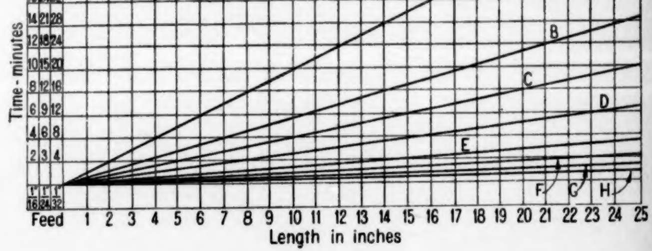


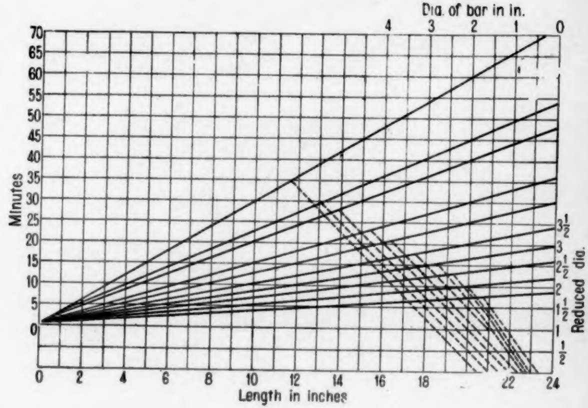
CHART C.





Spindle speeds shown by different graphs A, B, C, etc. A—16 r.p.m.; B—28; C—40; D—62; E—112; F—196; G—280; H—430 r.p.m.

CHART G.



Time for reducing bar stock in turret lathes (single cuts only).

TABLE 4.

STANDARD TIME ANALYSIS.

Part No. 2222L. Drawing No. 15071. Date, 19/5/17.
Description of Operation : **Turning Complete.**
M/c. Tool No. 487. Class of M/c. Tool : **No. 16 Herbert Combination.**

Preparing.				Handling.				Machining.			
No.	Key.	Min.	Sec.	No.	Key.	Min.	Sec.	No.	Key.	Min.	Sec.
15	AN	5	0	15	BC	10	0	—	—	—	—
15	AN	5	0	15	T	—	15	—	—	—	
15	AY	5	0	15	L	—	5	—	—	—	
—	—	—	—	15	AT	—	7	—	—	—	—
—	—	—	—	15	L	—	5	—	—	—	—
—	—	—	—	15	AQ	—	7	—	—	—	—

	Min.	Sec.
Preparing	55	57
Machining	24	54
Handling	24	59
Efficiency, 80 per cent.		
Standard Time	63	0
Preparation Time	70	0

TABLE 5.

TURNING AND BORING SPEEDS. 42 BULLARD MILL. No. C.771.

	Mild Steel.			Cast Iron.	
Vertical ...	$\frac{1}{16}$" × 9th	$\frac{1}{8}$" × 9th	$\frac{1}{8}$" × 9th	$\frac{1}{4}$" × 9th	
Horizontal	$\frac{1}{8}$" × 10th	$\frac{1}{4}$" × 10th	$\frac{3}{8}$" × 10th	$\frac{1}{4}$" × 10th	Hard C.I.
4"	—	—	—	—	1st
6"	—	1st	2nd	1st	2nd
8"	1st	2nd	3rd	2nd	3rd
12"	2nd	3rd	4th	3rd	4th
16"	3rd	4th	5th	4th	5th
20"	—	4th	5th	5th	6th
24"	4th	5th	6th	6th	7th
30"	5th	6th	7th	6th	7th
36"	—	6th	7th	7th	8th
42"	6th	—	7th	7th	8th

For Rough Boring Cuts use 10th Traverse.
For Finish Scrapes (Broad Tools) use suitable Fast Traverse.

TABLE 6.

GRINDING HOLES $\frac{3}{4}$" TO 3" DIA. HARDENED. TOLERANCE .001".

Unit Operations ...	$\frac{3}{4}$" Seconds.				$1\frac{1}{4}$" Seconds.				$1\frac{3}{4}$" Seconds.			
Length	1"	2"	3"	4"	1"	2"	3"	4"	1"	2"	3"	4"
Chuck	20	20	20	20	20	20	20	20	20	20	20	20
Grind .010"	188	396	564	752	314	618	942	1236	436	872	1308	1744
Gauge	20	25	30	35	25	30	35	40	30	35	40	45
Remove	15	15	15	15	15	15	15	15	15	15	15	15
Allow for Wheel 5%	12	22	31	41	18	34	51	65	25	47	69	91
Fatigue Factor 5%	12	22	31	41	18	34	51	65	25	47	69	91
Actual Times Total	267	500	691	904	410	751	1114	1441	551	1036	1521	2006

	$2\frac{1}{2}$" Seconds.				3" Seconds.			
Length	1"	2"	3"	4"	1"	2"	3"	4"
Chuck	20	20	20	20	20	20	20	20
Grind .010"	619	1238	1857	2476	768	1536	2304	3072
Gauge	35	40	45	50	40	45	50	55
Remove	15	15	15	15	15	15	15	15
Allow for Wheel 5%	34	65	96	128	42	80	119	158
Fatigue Factor 5%	34	65	96	128	42	80	119	158
Actual Times Total	757	1443	2129	2817	927	1776	2627	3478

The time to gauge varies slightly according to the length of the hole, the variation being arbitrarily fixed at one second increase per inch of length. It is also said to vary as to diameter, this variation being fixed arbitrarily at 5 per cent. increase per ¼in. increase in diameter.

The next factor to be dealt with is removing work from the machine. When using Jigs or Chucks this has been fixed at 30 secs.; an analysis of the requisite motions shewing:—

(a)	Withdrawing wheel and stop machine ...	7 secs.
(b)	Unclamp	15 „
(c)	Remove piece from chuck or adaptor and place on floor	8
	Total	30 secs.

The time taken to true a grinding wheel can be treated as a percentage of the actual time the wheel is at work on a given surface. It is difficult to evaluate owing to the variation in the grade of wheels, the variation in the material and other obscure factors. Theoretically, all the other factors being constant the percentage would vary according to the diameter, the small diameter requiring a higher percentage owing to the smaller wheel glazing more frequently.

As it has not been possible (owing to the lack of data dealing with this factor) to go very minutely into this question, an allowance of 5 per cent. of the actual grinding time has been arbitrarily fixed in the expectation that it will cover all normal cases.

The fatigue factor also has been arbitrarily fixed and is considered a suitable one to use when considering grinding.

In the actual grinding of a hole the three factors of feed, speed of work and depth of cut largely determine the time taken to finish a hole. On small work the speed measured on the diameter of the hole usually varies from 20 to 40 ft. per min. It has been considered inadvisable to reckon on a greater speed than 20 ft. per min. The depth of cut possible varies in small work; generally it may be taken that the strength of the wheel and spindle determine the depth of cut and the chart is based on an appreciation of this fact. The minimum reduction per traverse is .00016in. for ¾ in. diameter rising by .00001 in. per ¼ in. to .00025 in. which is considered the heaviest reduction advisable on a 3 in. dia. hole.

The traverse is not easy to evaluate as it is hand-operated. It varies for the same reasons as those which control the depth of cut. The smaller the diameter of hole the finer the feed or traverse.

It is also necessary to make provision for withdrawing the wheel after traversing through the hole. This has been valued as equal to a quick return of 10 to 1 hence and an allowance of 10

per cent. has been made on the grinding time to cover it. Every care has been taken in determining the basis upon which these charts were constructed and provision has been made for normal, as well as certain well-defined abnormal conditions. However, any given time on the charts may be considered with high or low values if special or abnormal conditions enter into the production of any given batch of work. The following hypothetical cases illustrate this.

Say the time allowed is 10 mins. actual, and :—

(a) The operator is exceptionally efficient,
(b) The machine is in first-class condition
(c) The wheel is just right,
(d) The work is .002 in. or .003 in. consistently under the standard.

In fact, when all conditions are favourable, a batch is turned out at an average of 7 mins.

Then in the next batch :—

(a) The operator is slow and uncertain.
(b) The machine is in bad condition.
(c) The wheel is not just of the right grade.
(d) The work varies greatly from .003 in. under to say .004 in. over.

Then this batch is turned out in an average of 12 mins. each. Because of these varying results it should not be considered that the charts are wrong.

Greater variation in time will occur in grinding than in almost any other class of machine shop work, hence in investigating complaints re times for grinding, great care should be exercised in determining exactly where the faults lie.

Charts E, F, and G were constructed by me over 20 years ago to suit conditions obtaining in a large General Engineering shop. For E and F some hundreds of actual results were plotted and the mean line of actual times determined. To this was added all necessary allowances, and finally a line of basis times was plotted. These lines are shown on the charts, and are suitable for ratefixing under the Rowan Premium System.

As previously mentioned, I do not recommend this method, but it is useful under certain conditions.

I have now described what have been found to be reliable methods of ratefixing and means of recording data by the use of simple charts.

There are other methods of recording data which, under certain conditions, may be more convenient, but I do not purpose to deal exhaustively with these except to mention two

The first is by means of a slide rule a full description of which may be found in a paper by Carl Barth entitled "Slide rules for the machine shop," published in Volume 25 of the "Trans-

actions of the A.S.M.E." These slide rules are useful calculating machining units only. The second method is one devised and patented in 1906 by the Author and consists of a calculating instrument called "The Graphic Calculator," with appropriate scales. Particulars are to be found in the Technical Press of that year. A full description of the instrument with scales suitable for calculating the premium earnings under the Rowan Premium System can be found in the "American Machinist" of May, 1906, or 1907.

This method is better than the slide rule method in that the complete system of ratefixing outlined in this paper (i.e., Machining, Handling and Preparation Units with Efficiency Factor) can be included on the special scales used. Should any member desire fuller information I will be pleased to supply it. This instrument was used by me for a period of five years and I found it of great use.

I now propose reverting to motion study for the purpose of showing the advantages to be gained by making motion studies of operations actually being done to times fixed by the ratefixer. It it immaterial whether the ratefixer makes these studies or not, although personally I strongly hold the opinion that an official attached to the Planning Department should be made responsible (where circumstances warrant the whole time work of such an official). Let us call this official a demonstrator and specify his duties.

Armed with a copy of the ratefixers analysis (Table I.) he would:—

(1). Make a motion study of the operator's performance.

(2). Compare it with analysis.

(3). Take the necessary steps to (a) Satisfy the ratefixer of errors in his analysis; (b) cut out superfluous motions and eradicate the faults of the operator to enable him to work to schedule; (c) Notify the department concerned in regard to inefficiencies in the machine tool, jig, fixture, small tools, etc.

Appropriate forms would of course be used for these purposes. At the beginning of this paper I mentioned that I would not attempt to deal exhaustively with the historical or philosophical sides of the subject. I feel, however, that there are one or two aspects of the economic side I should like to touch upon, mainly in the hope that discussion may be provoked.

It is true that good ratefixing with all it connotes leads to prosperity but the Ratefixing Department where rates are guessed at on the basis of 80 per cent. miss and 20 per cent. hit is that which breeds antagonism, which is responsible for strikes, ca'canny and many of the other noxious growths that help to strangle industry.

Your efficient works manager desires peace and contentment in

his shops because he realises that the true measure of the success of his firm is not only the size of the dividend it pays its shareholders but the bonus it offers its employees (apart from the payment of good wages) in the shape of good conditions and contentment.

He cannot achieve this object unless his ratefixing staff is efficient.

It behoves, therefore, all who aspire to enter the ranks of the ratefixer, as well as those who have already enlisted, to realise how important their labours are in the industrial field, and to take to heart the words of Solomon, "Get knowledge, but above all get understanding."

Discussion on Ratefixing.

MR. HUTCHINSON: I feel that we must thank Mr. Ronald for what has been a very fine treatise on ratefixing, as Mr. Ronald conceives it. Mr. Ronald left out entirely one faculty that a ratefixer should possess, that of absolute confidence in himself. I do not think Mr. Ronald mentioned that at all. You may have as much knowledge as your head can hold, but unless you have the confidence to assert it, and to demonstrate it, then that knowledge in itself is of no use. Now Mr. Ronald made a very big point of the fact that when he has had ratefixers applying to him for jobs, they have invariably come along and said, "We have an enormous amount of data," and he has promptly told them to leave it at home.

Mr. Ronald is a ratefixer; he has been one, and he has evidently followed in the tracks of other people, because he has come along with piles of data, and I should like to ask Mr. Ronald how he substantiates his goodly advice after he has shown us this magnificent and very interesting data. At the same time I think it possible he may have brought along this data with the idea of demonstrating his point, because, although it is very fine and elaborate, I do not see that it takes us one whit further in the subject of ratefixing. It simply proves that you can get out data to study any particular case or circumstance. But you cannot get out data to cover any general view of ratefixing. The particular machining operation that he dealt with most largely, namely, grinding, I think shows this. He has got data which indicates what can be done in the question of grinding one particular kind of job, and it is, I take it, a jig bushing. That I suppose, is the very simplest form of grinding. There one has a very ordinary steel and one can go right ahead, and undoubtedly get down to a fairly fine chart to show exactly how long the operation ought to take, no matter what works in the country it is

done in. But when one comes to grinding for actual production (and after all the ratefixer is there in the production shop and not the tool room), one gets an entirely different set of circumstances arising. There are degrees of finish. Grinding allowances are covered by matters of distortion; speed of grinding is governed by the amout of distortion one is likely to get in the part; there are various alloy steels which one has to grind and which can be damaged unless they are ground with extreme care. Now those are the kind of points which one cannot put in the data, and thus, taking this one operation, and comparing it with the operation Mr. Ronald picked out, it shows how perfectly futile it is to try to deal with a subject of this sort in any degree of detail. I think we must appreciate the other side of Mr. Ronald's paper, that is the general knowledge which he has given us, and I am going to ask you to try to bring out from Mr. Ronald in the discussion, not so much a discussion on his charts, but to bring out that knowledge Mr. Ronald has in his head of the general difficulties with which you and the ratefixer are faced in your daily work.

Mr. Gerard Smith: As usual my question is more of organisation than the subject of the paper. I would refer particularly to Table 3 and put in a complaint against a man being allowed 20 minutes out of 55 minutes 57 seconds. The particular items I refer to are:—getting the job with instructions, etc, 5 minutes; writing out order for tools and going to stores, 5 minutes; looking out bolts, glands, etc., 5 minutes; writing out time card, 5 minutes. Is it not a fact that the whole of the ratefixers work has been thrown away by allowing a man to do those which are purely clerical functions? If one is going to have any organisation in a works, surely it is up to the progress department to do those things which are a third of the total of the preparing operations.

Going on to Table 4, the preparing operations take 56 minutes, the handling 25 minutes, and the machining 25 minutes. Therefore that 20 minutes which could be saved is a very considerable proportion of the whole job.

Regarding the rest of Mr. Ronald's paper, I have been out of the shops too long to quibble about the details on the charts, but I see a further difficulty. Mr. Ronald has not told us how we can fix a rate for a job that we have not previously performed. Admittedly one can get some of the details. One can get feeds, speeds and cuts, which are more or less in order, but surely one must be in a position to estimate if somebody designs a component in a way we have not seen before. For instance, the new method of grinding cylinders, which I believe is done with a very slow reciprocating motion instead of the high speed rotative grinding. Are we to wait until we have piled up data? In many shops a job comes through, and within 10 minutes it has to be on

the machine, it becomes then purely a question of experience, and there are, I feel, many jobs which cannot be rated at all. As an example, let us consider some of the press work in our own place. When first started we did not know how to perform it, as it was work which had not been seen before in this country, and I think Mr. Ronald will answer me by saying that one cannot ratefix it. If it can I should like to be instructed as to whether there is anything but experience which can help us in such a case.

Mr. Ronald: With regard to the first point, the preparation, the ratefixer, was held responsible in this case because the organisation was such that those things had to be done by the man at the machine. Consequently he had to fix the rate.

Mr. Gerard Smith: You would agree with it.

Mr. Ronald: No, but the ratefixer can only deal with facts that present themselves to him. The next, with regard to fixing a rate in front. In our own organisation all rates are fixed in front. We do not do all of it perfectly, but the ratefixer's experience simply boils down to the things he ought to have at his command. His knowledge of machining allowances, capacity of the machines, knowledge of the material, and the knowledge of handling times. If a ratefixer knows the machine tool intimately, if he knows the material intimately, there is very little difficulty in fixing a rate beforehand. Certain factors which are strange will undoubtedly present themselves, but he can always make a very close evaluation of these. There is no difficulty in fixing a rate to a very close approximation, even although the work has not been done before. He has a drawing, he knows the machine, the material and he knows the men. In something radically new he may be a little in doubt, but he is never in great error.

Mr. H. E. Weatherley: Perhaps Mr. Ronald will tell us how we can train a superman to be the ratefixer we appear to require. There are very few men who are conversant with the subject.

Mr. Ronald: The ratefixer, if he is not a superman, ought to be. He is generally considered to be so. Ratefixing like everything else, can be localised. For instance, if one is engaged in a very large shop, where all kinds of trades are being practised, one would not put a joiner to ratefix in a smithy, nor would one put a machinist to ratefix in the bar shop. One would take a man who is acquainted with that particular trade in which he was fixing the rates.

Mr. Weatherley: Mr. Ronald deals with the big factories. In a small factory one cannot get a man for every section, because it is not justified. That is the subject we should deal with, because the big factory can afford to do everything.

Mr. Ronald: The answer to that is that the employer for the small factory must search until he can obtain a man covering

the scope of his factory. There are many ratefixers who do know many trades. There are many men who can do more things than one, but in the main most of us can do one thing well. The ratefixer in that trade will have to be the jack of all trades.

A VISITOR: I am very disappointed in the lecture, because it appears to me that all the information and examples are more or less on repetition work. When I was working with my tools, I knew what the job was worth before the ratefixer gave it to me. What I was hoping to get when I came here was some information on general work; on examples of work which goes into the shop very, very rarely; work taking probably 50 or 60 hours to complete and involving a large amount of handling time. How does one arrive at data for that class of work? Repetition work is very easy, I can always size up to a few minutes any job given me.

MR. RONALD: The system that I have outlined in this paper is applicable to all kinds of machining work. I have had eight years' experience in a large, general engineering firm. No two jobs were alike, but the principles were the same for the large, small, or any other operation one cared to take. Some of the charts are for repetition work, some for general work. For instance, there is one chart dealing with flanges. These varied from very tiny little things to huge flanges weighing 7 or 8 cwt. The principle is the same. It is a question of degree, that is all.

MR. PATTINSON: I am in agreement with Mr. Weatherley regarding the proper people for the job. In the first place there is one thing that I have always found (and I have been a ratefixer myself) and that is that in ratefixing one always seems to forget one thing—fatigue. I will mention a little incident that happened in a large factory somewhat similar to Mr. Ronald's. A man being allowed 5 seconds handling time remarked that if his hand slipped he would be in debt. That is perfectly true, although at the same time the efficient ratefixer is not going to allow for a hand to slip. I would like Mr. Ronald to tell us what is his procedure when fixing rates. Does he fix rates for the machines as they stand in the shop or machine charts? Does he know the absolute efficiency or non-efficiency of those machines, or does he fix rates, which I hope he does, at 100 per cent. efficiency for the machines? What I mean is this. There are some machines which have no machine feed on, one has to feed them, and I have always found that one can tabulate those factors as allowances bearing a certain value. If the manager is alive he sees that the ratefixer is giving so much extra time as against time unit. That is to my mind a true guide as to the efficiency of the machine shops or the machines. Furthermore, I would like to know whether his fixers visualise a little. If they go to an exhibition and see a machine there which is doing the work much quicker and better,

say in half the time of any machine in the shop, what are those ratefixers going to do the next time they make a layout? It constantly should cross their minds that there is a certain machine on the market which will do the job in about half the time. My instructions to my people are that they can fix their rates for that ideal machine, although they have not got it. To my mind it is a great thing to visualise what one would like to get in the shops, and it is a good key to use when one decides to scrap machines and put in new plant. It tells immediately the class of machines wanted, because extra time has been paid for machines which are not efficient. I would also like to know Mr. Ronald's system of demonstrating in the shop. We have recently started premium bonus in almost every department, including the pattern shop, but excepting in the erecting, every single ratefixer on my staff is a practical man. The reason I did that is this, because as a workman I have suffered through the inefficiency of the ratefixing department. As an example, I took one of the blacksmiths from the forge, and I have a real first class man; he makes out the times, and if the blacksmiths say that the job cannot be done in the time, he says, "I will take my coat off and show you how to do it." The time studies are substantiated in practice by the man who makes the study if the men wish the time to be demonstrated. As a matter of fact we have had very few demonstrations to make, and the reason I mention that is because it seems to me to prove that we cannot be very far wrong in our time studies. There is one thing Mr. Ronald has not touched upon, where Mr. Weatherley's super ratefixer would come in. One of the biggest bugbears which I find is that we don't seem to be able to get down to the material. Rates are fixed for ideal conditions and ideal materials, but we have to go on giving allowances for hard and defective material, and that is one which we know the ratefixer cannot visualise. We do cover up a lot of the sins of our foundries and suppliers, and probably while we keep on doing that they will not mend their ways. I appreciate, too, our President's remarks about creating confidence in the shops. If men believe that the last ounce is to be extracted from them and there is no hope of getting any redress, then we shall not get very far with payment by results.

Mr. Ronald: The first point about the five seconds. I think I have covered that by asking the ratefixer to get knowledge and above all, understanding. Next, with regard to fixing rates for ideal machines found at an Exhibition. That cannot be done for there would be trouble in the shops. Rates must be fixed for the conditions as they are.

Mr. Pattinson: Probably I did not make my meaning clear. What I should have said was this:—Fix the rates for ideal conditions, then send the work out in the shops with plus allowance.

That plus allowance will meet the conditions in the shop, and when you get your ideal machine cut it out.

MR. RONALD: May I ask another question before I reply? What is the object of setting a rate for ideal machines if they are not in the shop, and why do it before the machines arrive? By all means notify the management that you have seen a better type of machine, but the average man cannot fix rates for an ideal shop and the ratefixer cannot live in an ideal world if he is to be of any use in the shop now.

As for the system of demonstrating. I think everybody agrees that there should be some organisation in the shop for demonstrating a rate if necessary. Where I am employed we have an organisation of that kind, and we use it if necessary. Our ratefixers are efficient, and we have very little demonstrating to do. When it has got to be done a trained machinist does it. I think that is the system in most places with an up-to-date efficient planning department.

MR. PATTINSON: I do not agree with your remarks about the ideal machine, because to-night you have presented us with a lot of figures and facts which you consider constitute the main theme, that is to get down to minimum cost. I cannot see any better scheme and I have proved it in practice that, if I see a whole lot of allowances made and I can analyse these allowances in the ratefixing department, it brings home very forcibly to me there is something wrong. Surely there is no harm in having that on record, and using it as a guide when buying machines. Furthermore, if it is put on as an allowance, I can illustrate that point a little further. We had some printing cylinders to machine a short time ago; they were about 6ft. long and 15 or 16in. diameter. When that rate was fixed we made a time study to do those cylinders with two tools on a double saddle on the machine. The rate went in to the shop as the fixed rate of two saddles, but there was a plus time put on until the extra saddle was made in the tool room, and then the original price was substantiated. I think if that is done the ratefixers get a good idea of looking round the shops and seeing what they can do in the way of improvements.

MR. RONALD: I think you are misunderstanding the spirit of this paper. I tried to make it quite clear that this paper deals with fixing rates, simply as a duty that the ratefixer has to perform in a particular shop with particular machines and particular methods. The question as to whether he deals with some ideal machine is purely a matter for the management involved. If they wish that sort of thing to be done, it can be done, but it is not a necessary part of a ratefixer's duty. It is for the other sections to improve matters. He has only to fix rates for the things he finds. I have noted in my paper that the demonstrator, in making

a motion study after a time has been already fixed, should be made in my opinion, to report general inefficiency, or any machine tool, material or any other inefficiency, may prevent the operator from producing work to the time schedule. If he cannot make that time, then there is an error in it, either the ratefixer has made a mistake, or there is something wrong with the machine. If hundreds of rates have to be fixed in a week, it just gives the ratefixer double the amount of work to do if he considers something that does not exist.

A VISITOR: I have been interested in the remarks which have been passed. It seems to me that the paper has been written round what I should call a ratefixer's Utopia. For instance, the firm I am connected with are more or less general engineers. We have our standard lines but at the same time we undertake anything. One of our difficulties in ratefixing is this:—We get an inquiry, a price is put in and the order goes down to the planning department. The operation is planned for certain machines but by the time it gets into the shop those machines are already occupied on other work, consequently another price has to be fixed. A few weeks ago I was in the Midlands, and a system there with regard to fixing prices on automatic lathes is as follows:—The foreman of the shop received the job and the drawing. He tooled up the job to the best of his ability, demonstrated that it could be done, then the ratefixer came along and gave a price. We were rather impressed by this method, so impressed that we are going to give it a trial.

There is another question I would like to ask. What ought to be the connection between the ratefixing department and the planning department with regard to estimating? Should they be one, or separate departments? I should also like to have his remarks with respect to a foreman of a general engineering shop fixing his own prices.

MR. RONALD: The connection between planning, ratefixing and estimating, and as to whether these departments ought to be one or separate, is entirely a question for the management. At one period I had control of the estimating, ratefixing and planning and not only that, I was responsible for the work coming through the shops. It is a question of the size of the shop, and various other things, but this much I may say, there should be no estimating done by men who are purely clerical men. I think it is a mistake that many firms make. Estimating should be done on a basis which springs straight from the ratefixer.

A VISITOR: You passed absolute condemnation on the guessing ratefixer. It appears to me that it is all guessing.

MR. RONALD: It is rather a difficult subject. There are guesses and guesses. The trained man guesses, but he instinctively knows. He does not consciously visualise the work he has

got to ratefix, but unconsciously he does so. There are certain operations of the brain which take place, and the person who possesses that brain does not know it is taking place. A pattern maker might look at a piece of work, and unconsciously determine how long it would take, and put the time as accurate as if consciously considered. It is a guess, but an inspired guess. As far as ratefixing being guessing, where definite data can be accummulated, and definite means be studied then it is only a case of selecting them. It is a question of applying them to the particular piece of work being dealt with. Many ratefixers do guess, but their "guess" is based on knowledge.

Mr. E. W. Hancock: My views on ratefixing are these. First of all I do not like the term "ratefixing." I do not think a man ought to be called ratefixer, he ought to be called an engineer, and I think that ratefixing such as we are discussing, starts with planning, and the ratefixer should be an engineer of planning. In certain classes of work it strikes me that there is no function in an organisation for what we term an absolute ratefixer. To me it seems that the body of engineers who plan a certain efficiency for certain floor area have to plan their machines according to the system of times. Those times are compiled by engineers based on a broad knowledge of the subject by instinctive guessing. The demonstration which the author mentioned backs up these instinctive thoughts and gives the man in the shop before his rate is finally fixed, a real and true time. Then having fixed that time for the man by able and competent demonstrators, it seems to me that all that is required is to put the time down. It is then merely a clerk's job. Ratefixing on certain organised work rests between two bodies, the planning engineers and the demonstrators, and beyond that I see no further function for any other body of men, other than a clerical staff.

Mr. Ronald: I think I agree with what the speaker has said there. One can call the man ratefixer or an efficiency engineer as one wishes. He has got to plan and fix a rate, and he fixes the rate by some manner in which he makes his analysis. A rate ought not to be fixed after the job is in the machine. It should be done first and one has to analyse to do that.

Mr. Hancock: I think the following is a point of interest. One method of getting rates fixed in an American shop I was in is rather amusing. They had no ratefixers or people watching very closely. An estimated time was put down, and against this time was placed the letter "E" to show that it was an estimated time, and they allowed the men to make as much money as they liked. The men went mad on the job, turning over twice or three times their weekly money, knowing that eventually the rate would be cut down. I do not agree that it would function in this country,

but it struck me as rather a novel method of getting down to the shortest time.

A Visitor: I am sure the author will forgive me going back to the point Mr. Pattinson has raised regarding the ideal machine. I want this explained to me with regard to ratefixing. Supposing one has half a dozen drilling machines. The best of them is the latest high speed ball bearing machine, and the worst is probably very old. In fixing a rate for a certain drilling operation, should one fix that rate for the machine the job is going on, or should one fix the time for the best machine? I most strongly agree with Mr. Pattinson's idea to fix the rate for the best machines in the shop. If that is not done one gets different rates, causing discontent, and there is nothing worse in any shop. One factor of efficiency in the shop is to have contented employees, and if there are various rates in the shop for the same job, there will be chaos everywhere.

Mr. Ronald: If one fixes a rate for the best machine in the shop, what is going to happen to the fellow on the worst machine? Supposing a battery of machines which differ in efficiencies: a rate has to be fixed for each machine according to its efficiency, or one has to fix one rate. There is a choice of rate; for the best, for the worst, or for the machine in between. If for the best machine, what happens to those who are working the worst machines? In the end a rate is being fixed for each machine. Why not do it at once and have done with it?

A Visitor: Supposing I have to fix a rate for a bad machine and the time comes out to 12 hours. Next week the same job goes to a good machine. That operator has got to have three hours less. It makes a lot of trouble, but if I put it at 9 hours plus 3 for the bad machine, I say "Yours is a good machine, you have no plus allowance."

Mr. Ronald: I do not see the point. You have given them, in each case, the same amount of time. The bad machine is still getting the same time whether you put it 9 hours plus 3 or 12 hours.

Mr. Storey: Mr. Ronald seems to have missed the point, that for psychological reasons it is better to give a plus allowance than a minus allowance, and I think a ratefixer should be a psychologist.

Mr. Ronald: I thought that would arise. I do not agree that psychology exists in that case. The men realise that 12 hours are 12 hours whether expressed as 6 and 6, or 9 and 3. That is my experience. I do not think the men are quite so unintelligent at the present day as to be misled by the suggestion that 9 plus 3 is different from 12.

Mr. Salmon: There is one point which rather struck me, that is that the paper is really an analysis of time study. I would like to touch on Table 1, dealing with the Herbert No. 16 com-

bination lathes. The first two items, A and B, strike me as rather peculiar, because on No. 16 combination lathe any operator, whether he is skilled or not, tires before the end of the day. For instance, take the hub, a very weighty piece. To lift that needs a small crane and that in itself would take more than two minutes. It has been my experience over many years gained, that all this data is not necessary to evaluate the time wanted on a piece.

Mr. Ronald: I explained in my paper that the data was taken 15 years ago. I made it clear that this was an illustration of a method of analysis, and specifically stated that it must not be taken as useful data, being given to show methods of analysis to illustrate a principle.

Mr. Rich: A previous speaker mentioned the allowance for two types of drilling machines. To a very large extent I agree with him, but on the other hand I wish to say that if an up-to-date manufacturing firm has a machine that is 25 per cent. less efficient than the others, I think that it is about time that the management replaced it by a more up-to-date machine.

Mr. Pattinson remarked upon the difference in material. Where I am engaged we have different steels of different tensile and it is the first duty of a ratefixer when he is laying out a job, to take into account the softness or hardness of the material. The first thing a ratefixer has to do is to find out the material to be worked upon, and he works out an analysis.

A Visitor: Most of the remarks regarding ratefixing have been on machine work. Comparatively speaking that is child's play. What I came to hear, was something on hand labour. The author has not made any reference to that at all. Fitting operations, pattern making, moulding, painting, even white-washing. I do not know whether Mr. Ronald could give us any data regarding these operations.

Mr. Rich: I remember some years ago putting the price on the work of tarring corrugated iron.

Mr. Ronald: I also fixed that operation 13 years ago, and a time for washing cars, and I used the same method of analysis for washing cars as I used for fixing a rate on a machine. The same methods because the principles are true.

Mr. Hutchinson: There has been very little said to-night about wage systems, and I expected to hear a lot, because the paper condemned all types of wage systems. Now, to my mind, the wage system (and the ideal one has yet to be invented) is one of the most important matters in present day production.

In connection with ratefixing we have had an example given of three men, the fast operator, the medium operator and the old hand. The ratefixer's duty is to fix a mean average time. It is obviously impossible for him to fix a time which would be equal to

all three classes of men. There is no reason why when he has fixed his mean time, a wage system cannot be evolved which equalises the three classes of operator. We get it very nearly in the Rowan system, where the bonus earned is very low to start with and gradually dies down until it is theoretically possible for a man to earn double time. Possibly that system does not give sufficient inducement to the quicker workmen, and it might give too much protection to slower workmen, but I do believe that some means between the Rowan system and the Halsey system should be evolved. I do not consider that a ratefixer should be asked to fix rates for men of different speeds of work.

The analysis charts we have seen to-night are a very great help even if the rates are fixed. I think that when a job is running, it is essential that every man who is responsible for production in any way will make certain and see that a motion study chart is got out of the job to be produced. It is only by motion study that one can see the weak points on which one can save time on any job. Analyses are essential; although not necessary in the first instance to fix the rate, they are certainly essential afterwards to check the rate. If too big a time is put on a job it should be discovered by a man earning too much money. Unfortunately, it is not because an operator will always cut his coat according to his cloth. Therefore the natural result of putting too high a time on the job is to get a smaller production than one should, and it is only by time analysis one is able to discover that that is taking place, and even then some of the operators are so smart that it is very difficult to find out with careful analysis the state of affairs.

We have got to appreciate that the author dealt in an extremely able manner with that part of the subject he touched upon. He has given us good food for thought and something to discuss. He said he realised that a paper on ratefixing was very difficult to write, but it might become very instructive if he could only induce a good discussion, and I think in that he has succeeded very admirably.

CORRESPONDENCE.

Sir,—I am enclosing a sketch and description of an Improved Gudgeon Pin which I have designed. This has been jointly protected by myself and my employers (Messrs. The Scott Motor Cycle Co., Ltd.) but it will doubtless interest members of the Institution, especially those engaged in Automobile and Aircraft engine manufacture.

It will be seen that instead of using an aluminium cap at the

end of the gudgeon pin to protect the walls of the cylinder an aluminium tube is used. This is a push fit through the pin and is then spun over to form a flange or rivet.

The point which will interest members is that a more satisfactory job results with a great saving in production costs and without any sacrifice of accuracy.

The pin is drilled with a standard 7/16 in. twist drill and the tube is solid drawn to 7/16 in., less .002 in. The distortion caused by spinning the tube is negligible; the greatest we have experienced being .0001 in. The flange fits into a recess in the piston and this is necessary on a two-stroke engine to prevent the end being sheared off by the ports in the cylinder walls. We found it expedient on the old type caps to drill a hole in the small cap to nullify the suction effect of the inlet port otherwise the cap was drawn against the cylinder.

On the new type protector our times are as follows:—Cut off .3 mins. Fit tube, form flange 1.7 mins. Turn tube end and Polish 1.5 mins. Total 3.2 mins

The old type necessitated six operations and involved a total of 16.6 mins.

I hope these few notes may be of help and interest to the members of the Institution and if there is any further information required I shall be pleased to answer enquires either through the Journal or by post.

A. DEWHIRST, Assoc. member,

52, Clifton Place,
Shipley, Yorks.